PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

NEW SERIES.
VOL. X.

WHOLE SERIES.
VOL. XVIII.

FROM MAY, 1882, TO MAY, 1883.

SELECTED FROM THE RECORDS.

BOSTON:
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PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

VOL. XVIII.

PAPERS READ BEFORE THE ACADEMY.

I.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON CERTAIN SUBSTANCES OBTAINED FROM TURMERIC.—II. CURCUMIN.

By C. Loring Jackson and A. E. Menke.

Presented May 10th, 1882.

In the following paper* we have the honor of laying before the Academy a description of our experiments on the action of nascent hydrogen and of bromine upon curcumin.

Action of Nascent Hydrogen.

Dihydride of Curcumin, $C_{14}H_{16}O_4$. This substance was made by the action of sodium amalgam and water upon curcumin. The best result was obtained when a mixture of curcumin, dilute alcohol, and strong sodium amalgam was allowed to stand for somewhat more than a week. The alcohol, though not absolutely necessary, as the sodic hydrate formed gradually brings the curcumin into solution, accelerates the action, which at best is extremely slow. After the dark-red color of the sodic salt of curcumin had given place to a blackish tinge, the liquid was poured off from the mercury, acidified with hydrochloric acid, the fawn-colored precipitate thus obtained washed till free from acid, and dried *in vacuo*. A combustion gave the following results: —

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* The first paper was published in these Proceedings, Vol. XVII. p. 110.

0.2290 g. of substance gave 0.5678 g. of CO_2 and 0.1312 g. of H_2O.

	Calculated for $C_{14}H_{16}O_4$.	Found.
Carbon	67.74	67.63
Hydrogen	6.49	6.36

Properties. It forms a brownish white powder melting in the neighborhood of 100°, but with no definite melting-point; it is insoluble in water, freely soluble in alcohol and glacial acetic acid, slightly in ether, and insoluble in ligroine and benzol. Strong sulphuric acid dissolves it with a reddish-brown color, very different from the purple produced by curcumin. Sodic hydrate dissolves it on warming, and so does sodic carbonate; but the latter solution becomes turbid, and throws down a brownish precipitate on cooling.

The addition of hydrogen to curcumin by sodium amalgam and dilute alcohol is a tedious process occupying more than a week and giving a very bad yield, the product being frequently accompanied by a viscous substance, probably formed by the action of air on the alkaline solution of the hydride. A much better method of adding hydrogen to curcumin consisted in treating it with zinc dust and acetic acid, although in this case the hydride at first produced was further modified in the course of the reaction.

Anhydride of Curcumin Dihydride, $(C_{14}H_{15}O_4)_2O$. Curcumin was warmed with acetic acid of 85 per cent and a large quantity of zinc dust, the temperature being kept below the boiling-point of the acetic acid. After some hours the yellow color of the solution had become replaced by a dark brown, and if then a little of the substance gave a yellow instead of a red color with sodic hydrate, the heating was discontinued, and the liquid filtered into water, which precipitated fawn-colored flocks similar to those of the preceding compound. After we had satisfied ourselves that it was impossible to crystallize the substance, we purified it by resolution in glacial acetic acid and precipitation with water; but even this treatment did not remove the whole of the zinc salt, as was shown by the appearance of a slight ash on combustion. This has been subtracted from the weight of the substance taken in calculating the percentages.

The same substance was obtained when curcumin was heated with zinc dust and a solution of ammonic hydrate. The combustion marked III. was of a product made in this way: —

The substance after thorough washing with water was in each case dried on a steam-radiator at a temperature of about 60°.

I. 0.2552 g. of substance gave 0.6460 g. of CO_2.
0.1476 g. of H_2O. Ash = 0.004.
II. 0.2449 g. of substance gave 0.6183 g. of CO_2.
0.1368 g. of H_2O. Ash = 0.0061.
III. 0.2357 g. of substance gave 0.6001 g. of CO_2.
0.1365 g. of H_2O. Ash = 0.002.

	Calculated for $C_{28}H_{30}O_7$.	Found.		
		I.	II.	III.
Carbon	70.42	70.14*	70.61*	70.03*
Hydrogen	6.25	6.53	6.36	6.48

Properties. It resembles the dihydride closely, like it forming a dirty white powder with no definite melting-point, since it melts gradually in the neighborhood of 120°. The best solvents for it are alcohol and glacial acetic acid, but it is deposited on evaporation of the solvent as a varnish. It is essentially insoluble in ether, ligroine, and benzol, slightly soluble in chloroform. A solution of potassic hydrate dissolves it with a yellow color, while potassic carbonate forms a dark-brown solution if boiled with it, but as this solution cools, brownish flocks are deposited, which we supposed to be a potassium salt, until two analyses of the substance showed that it did not contain more than 2.5 per cent of potassium, whereas the salt with the least possible amount of the metal contains 7.5 per cent. It is evident, therefore, that the potassium was an impurity, which could well be, since we were able to find no satisfactory method of purification. An attempt to make a potassium salt with alcoholic potassic hydrate gave a black liquid, insoluble in a mixture of alcohol and ether, and of the most unpromising appearance.

The fact that the substance forms no salt with potassic carbonate indicates that the two molecules of the dihydride are connected by the removal of water from their carboxyl groups; but we did not consider the nature of the substance satisfactorily explained until we succeeded in making it from the dihydride, $C_{14}H_{16}O_4$, by the action of an acetic-acid solution of zincic acetate. After warming the two substances

---

* If the ash is not subtracted the percentages are, —

I.	II.	III.
69.04	68.85	69.44
6.43	6.20	6.43

together for some time, the product was treated with water, and the precipitate washed, dried, and analyzed, with the following result: —

0.1430 g. of substance gave 0.3666 g. of CO_2 and 0.0868 g. of H_2O.

	Calculated for $C_{28}H_{30}O_7$.	Found.
Carbon	70.42	69.92
Hydrogen	6.25	6.68

Whereas before this treatment a portion of the same sample gave carbon 67.63, hydrogen 6.36, as on page 2. This experiment proves, therefore, that the nascent hydrogen given off by zinc dust and acetic acid first converts the curcumin into the dihydride, from which the zincic acetate afterward removes one molecule of water. The anhydride is broken up only incompletely by the action of water at high temperatures or by boiling with sodic hydrate, the product in each case being a mixture of the dihydride and its anhydride.

In order to study the oxidation of the dihydride, some diethylcurcumin, prepared according to the method given in our first paper, was treated with zinc dust and acetic acid. The product thus obtained gave the following results on analysis, which indicate that it is a mixture of di- and monoethylcurcumin dihydride: —

I. 0.2130 g. of substance gave 0.5484 g. of CO_2 and 0.1415 g. of H_2O. Ash 0.0004.

II. 0.1938 g. of substance gave 0.4986 g. of CO_2 and 0.1336 g. of H_2O.

	Calculated for $(C_2H_5)C_{14}H_{15}O_4$.	Found.		Calculated for $(C_2H_5)_2C_{14}H_{15}O_4$.
		I.	II.	
Carbon	69.56	70.35	70.15	71.05
Hydrogen	7.25	7.40	7.66	7.89

Some of this substance was mixed with a saturated neutral solution of potassic permanganate and allowed to stand at the ordinary temperature. The oxidation took place very slowly, several weeks' standing being necessary to complete the reaction. The principal product was proved by its melting-point to be ethylvanillic acid, while the presence of a small quantity of ethylvanillin was indicated by its characteristic smell.

The most striking fact in connection with this reaction was that the dihydride was oxidized with so much more difficulty than curcumin itself.

Action of Bromine on the Anhydride of Curcumin Dihydride. When the hydride, dissolved in glacial acetic acid, was mixed with an excess of bromine and allowed to stand over night, the liquid turned black, and upon addition of water, a red precipitate was thrown down, which was washed with water, dried, and analyzed, —

I. 0.6652 g. of substance gave 0.7160 g. of CO_2 and 0.1122 g. of H_2O.
0.3100 g. gave according to Carius 0.4125 g. of AgBr.

II. 0.3202 g. gave 0.3498 g. of CO_2 and 0.0562 g. of H_2O.
0.2786 g. gave 0.3730 g. of AgBr.

	Calculated for $C_{14}H_{10}Br_4O_4$.	Found.	
		I.	II.
Carbon	29.89	29.36	29.80
Hydrogen	1.78	1.87	1.95
Bromine	56.94	56.62	56.99

The substance is red and amorphous; it does not melt under a red heat, but seems to be decomposed without melting. It is insoluble in water, ligroine, and benzol, very slightly soluble in alcohol and ether, soluble in glacial acetic acid. Strong sulphuric acid has no action upon it. It is vigorously acted on by boiling potassic hydrate, forming a red solution, from which acids precipitate a black tarry body which we were unable to purify; two analyses of its sodium salt, however, showed that it contained about the same percentage of oxygen as of carbon, and that most of the bromine (all but 7 per cent) had been removed, proving that the bromine in the original substance is all in the side-chain.

Action of Bromine on Curcumin.

We have obtained two bromine compounds of curcumin, one containing four and the other seven atoms of bromine.

Tetrabromide of Curcumin, $C_{14}H_{14}Br_4O_4$. When curcumin suspended in carbonic disulphide is allowed to stand with an excess of bromine for some hours, it is converted into a white substance, which is left as the carbonic disulphide evaporates. The carbonic disulphide can be replaced by glacial acetic acid, but in this case an excess of bromine or the use of a large quantity of glacial acetic acid must be avoided. The nature of this body could not be established satisfactorily by analysis, as it was more or less decomposed by all its solvents, and therefore a thorough purification was impossible; we have obtained one fair analysis, however, of a sample washed with carbonic disulphide.

0.2375 g. of substance gave according to Carius 0.3180 g. of AgBr, —

	Calculated for $C_{14}H_{14}Br_4O_4$.	Found.
Bromine	56.66	56.99

Other specimens contained the following percentages: —

Bromine	54.87	58.51	58.57

To confirm this result, which points to the taking up of four atoms of bromine, we determined the increase of weight caused by the bromine. For this purpose carbonic disulphide and bromine in excess were added to a weighed amount of curcumin, and the product weighed after drying it a little below 100°.

I. 0.252 g. of curcumin gained 0.354 g.
II. 0.218 g. gained 0.300 g.

These results correspond to the following percentages of bromine in the product, —

	Calculated for $C_{14}H_{14}Br_4O_4$.	Found.	
		I.	II.
Bromine	56.66	58.41	57.91

And there is therefore no doubt that the substance contains four atoms of bromine. To decide whether it was an addition or substitution product, we determined the amount of hydrobromic acid given off, as in every preparation an evolution of this gas was observed. For this purpose the gases formed in the reaction were allowed to pass through water, and finally the carbonic disulphide and excess of bromine were removed, at first from the curcumin, and afterward from the absorbing water, by a stream of air; the hydrobromic acid collected in the water was then determined as argentic bromide. One gramme of curcumin was used in each case, and in the following comparison of results the amounts found are compared with the calculated amount if the curcumin had given off two molecules of hydrobromic acid, —

Two Molecules HBr.	I.	II.
0.66	0.185	0.28

From this it appears that the hydrobromic acid is produced by an insignificant secondary reaction, and that the substance is an addition product, and therefore has the formula $C_{14}H_{14}Br_4O_4$.* We may add that some experiments to determine directly the number of molecules of bromine added pointed to two molecules as the probable amount, but the results are not definite enough to make them worth publishing.

Properties. It is a white or whitish amorphous substance, melting in the neighborhood of 185° with decomposition, but it has no definite melting-point. It is insoluble in water, soluble with decomposition in alcohol and in glacial acetic acid, which acts upon it, however, less rapidly than the alcohol, very slightly soluble in ether, chloroform, and carbonic disulphide, insoluble in ligroine and benzol. Its behavior with various reagents was taken up, but no results were obtained which promised to repay further study. The following observations, however, are of some interest. Potassic hydrate and also argentic oxide convert it in part into vanillin, to judge from the smell, while both anilin and zinc cleaned with sulphuric acid act upon it, the former with considerable evolution of heat, — thus confirming the inference that it is an addition-product. The principal products from these reactions, as well as those from the action of sodic carbonate and water, and of reducing-agents, are ill-defined bodies which we could find no means of purifying.

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* The high percentages of bromine obtained in the analyses may be accounted for by this secondary reaction.

Pentabromcurcumindibromide, $C_{14}H_9Br_7O_4$. If curcumin in glacial acetic acid is treated with an excess of bromine, or the solid tetrabromide treated with bromine, a red substance is formed, which, after washing with water and drying *in vacuo*, gave the following results: —

0.2898 g. of substance gave 0.2230 g. of CO_2 and 0.0304 g. of H_2O.
0.2666 g. of substance gave according to Carius 0.9323 g. of AgBr.

	Calculated for $C_{14}H_9Br_7O_4$.	Found.
Carbon	20.97	20.98
Hydrogen	1.12	1.16
Bromine	69.91	69.02

Properties. A red amorphous substance melting near 120°, but without definite melting-point; insoluble in water, soluble in alcohol apparently with decomposition, easily soluble in ether and glacial acetic acid, leaving a varnish, slightly soluble in benzol, insoluble in ligroine. Strong sulphuric acid acts on it very slowly, finally turning it a more brilliant red. Our study of the behavior of this substance has led to no more definite results than in the case of the tetrabromide.

Heated alone, it gives off bromine and hydrobromic acid, leaving a black tar, from which a yellow substance containing bromine can be extracted by alcohol; we may study this experiment more carefully hereafter. Sodic hydrate, sodic carbonate and water, sodic alcoholate, and argentic oxide, all act upon it, but no smell of vanillin was observed in any case. The same is true of several oxidation experiments we have tried upon it, and this would seem to indicate the presence of a portion of the bromine in the benzol ring. It is an interesting fact that potassic dichromate and sulphuric acid, and also neutral potassic permanganate, attack this substance only with extreme difficulty, whereas they both act vigorously on curcumin.

SUMMARY.

1. Curcumin takes up two atoms of hydrogen when treated with nascent hydrogen.

2. The dihydride thus formed passes over easily into an anhydride by losing one molecule of water.

3. The anhydride of diethylcurcumin dihydride is much less easily attacked by oxidizing agents than diethylcurcumin, but the products are the same, — ethylvanillic acid with a trace of ethylvanillin.

4. Bromine removes two atoms of hydrogen from the dihydride, and replaces four more, forming $C_{14}H_{10}Br_4O_4$.

5. Only four atoms of bromine can be added to curcumin.

6. The tetrabromide has a great tendency to form vanillin when treated with substances which remove bromine.

7. With an excess of bromine a substance, $C_{14}H_9Br_7O_4$, is formed.

8. The pentabromcurcumindibromide is oxidized in neutral or acid solutions only with great difficulty.

The observations just described throw some light upon the nature of the side-chain of curcumin, but as the inferences to be drawn from them are at best extremely doubtful, we shall postpone all discussion of the structure of curcumin until our further study of it has put the subject on a more secure basis.

III. TURMERIC OIL — TURMEROL.

The oil obtained from turmeric, which amounts to about 11 per cent of its whole weight, has naturally attracted the attention of chemists much less than curcumin, the yellow coloring-matter of the root; we find consequently only a few analyses and some meagre statements about the action of reagents upon the oil, in place of the much fuller study to which curcumin had been submitted. The most important of these will be found in the papers of Ivanow-Gajewsky* and Kachler,† but as they all refer to mixtures, it is not necessary to repeat them here. The oil, however, is not without practical interest, as to it the turmeric (and therefore curry powder) owes its aromatic taste and smell.

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* Ber. d. ch. G. 172, p. 1103.

† Ber. d. ch. G. 170, p. 713.

The crude product with which we started in the following study of the oil was extracted, from ground Bengal turmeric with ligroine, in the way already described in the first paper* of this series. After being freed from the higher boiling portions of the ligroine by heating to 150° in a boiling-flask, it formed a rather thick oily liquid, with a yellow color, and pleasant aromatic smell. The purification offered some difficulty, because it was decomposed by distillation under ordinary pressure, giving distillates with a rank, disagreeable smell; and distillation with steam, although effecting a partial purification, was an extremely tedious process, owing to the difficulty with which the oil was driven over. We were therefore obliged to resort to fractional distillation under diminished pressure, and in this way at last succeeded in separating the oil into three fractions, — the first, boiling below 193° under 60 mm. of pressure; the second, from 193°–198°; and the third, the retort residue, a viscous, semi-solid body of extremely uninviting appearance. We have up to this time confined our attention to the middle fraction, although a few experiments on the fraction below 193° would indicate that it consists of the middle fraction contaminated with hydrocarbons from the ligroine used in the extraction of the oil, — a view which is borne out by the very small amount of this fraction. For the fraction from 193°–198°, which is the subject of this paper, we would propose the name *turmerol.*

Composition of Turmerol.

I. 0.1924 g. of the oil gave 0.5903 g. of CO_2 and 0.1814 g. of H_2O.
II. 0.3126 g. gave 0.9588 g. of CO_2 and 0.3010 g. of H_2O.
III. 0.2354 g. gave 0.7157 g. of CO_2 and 0.2190 g. of H_2O.
IV. 0.2002 g. gave 0.6123 g. of CO_2 and 0.1818 g. of H_2O.
V. 0.2448 g. gave 0.7492 g. of CO_2 and 0.2306 g. of H_2O.

	I.	II.	III.	IV.	V.	Mean.
Carbon	83.68	83.66	82.90	83.43	83.47	83.62
Hydrogen	10.47	10.70	10.34	10.10	10.47	10.42

I.–III. are analyses of the same sample; IV. and V. analyses of a different sample. To test the purity of the oil, the original sample was distilled again *in vacuo*, and collected in three equal fractions. Of the analyses which follow, VI. was made with the portion which came over first; VII. and VIII. with that which came over last.

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* These Proceedings, Vol. XVII. p. 110.

VI. 0.3315 g. gave 1.0194 g. of CO_2 and 0.3145 g. of H_2O.
VII. 0.2837 g. gave 0.8675 g. of CO_2 and 0.2604 g. of H_2O.
VIII. 0.2706 g. gave 0.8228 g. of CO_2 and 0.2474 g. of H_2O.

	Lower Fraction.	Higher Fractions.	
	VI.	VII.	VIII.
Carbon	83.86	83.39	82.92
Hydrogen	10.54	10.20	10.16

From this it appears that the substance is essentially pure and homogeneous.

As has been stated already, the turmerol can be purified to a certain extent by distillation with steam; analysis IX. was made with a sample prepared in this way, while X. was made with some of the same sample after it had been distilled once under ordinary pressure. These specimens were extracted with carbonic disulphide instead of ligroine.

IX. 0.2260 g. gave 0.6860 g. of CO_2 and 0.2195 g. of H_2O.
X. 0.2636 g. gave 0.8038 g. of CO_2 and 0.2546 g. of H_2O.

	IX.	X.
Carbon	82.78	83.16
Hydrogen	10.77	10.73

The analyses unfortunately are not capable of establishing the formula of turmerol with certainty, since the difference between the members of the homologous series is very small, as is shown by the following comparison: —

	Mean of the Preceding Analyses.	$C_{18}H_{26}O$.	$C_{19}H_{28}O$.	$C_{20}H_{30}O$.
Carbon	83.62	83.73	83.81	83.90
Hydrogen	10.42	10.08	10.29	10.49

Taking both the hydrogen and the carbon into consideration, our results agree best with the formula $C_{19}H_{28}O$, as shown above in the case of the mean, and a comparison of the separate analyses with the calculated percentages also declares in favor of this formula. But it is evident that it is impossible to decide definitely from these data in favor of this formula, nor can the derivatives we have prepared from the oil settle this question, as a thorough purification of these bodies has proved impossible on account of their ill-defined properties and slight stability.

We are inclined to ascribe the differences between analyses VI. and VII. and VIII. to the presence of a trace of some hydrocarbon from the ligroine, but did not attempt to purify the substance further, as it is slightly decomposed, even by distillation, under a pressure of 60 mm.

Properties of Turmerol.

The substance analyzed by us had a pale yellow color, an agreeable, not very strong aromatic smell, and a specific gravity of 0.9016 at 17°. It turns a ray of polarized light to the right with the following specific rotary power for sodium light: —

$$[\alpha] = 33.52.$$

Under ordinary pressure it boils at 285°–290°, but decomposes apparently with formation of water, giving a substance with a lower boiling-point. At a pressure of 60 mm. it boils from 193° – 198°, but even under this pressure suffers a slight decomposition. It is essentially insoluble in water, but mixes easily with all other common solvents. Acid sodic sulphite in aqueous solution has no action upon it.

In order to determine the nature of turmerol, its behavior with various reagents was next studied.

Action of Hydrochloric Acid. Turmerylchloride.

When turmerol was heated with aqueous hydrochloric acid saturated at 0° to 150° in a sealed tube for some hours, a brown oily liquid was formed having a different smell from the original substance, which, when washed until free from acid and dried *in vacuo*, gave the following results on analysis: —

I. 0.2938 g. of substance gave 0.8464 g. of CO_2 and 0.2530 g. of H_2O.

0.4434 g. of substance gave according to Carius 0.2190 g. of AgCl.

II. 0.3179 g. of substance gave 0.1518 g. of AgCl.

	Calculated for $C_{19}H_{27}Cl$.	Found. I.	Found. II.
Carbon	78.48	78.57	
Hydrogen	9.30	9.57	
Chloride	12.22	12.21	11.80
	100.00	100.35	

Analyses I. and II. were made with specimens from different preparations. The substance was a pale brownish oil with an agreeable smell, different from that of turmerol; it decomposed on distillation, and also lost chlorine when distilled with steam or even with fuming hydrochloric acid.

The same compound was formed by the action of phosphorous trichloride on turmerol, but much less neatly. Phosphoric pentachloride, on the other hand, seemed to add chlorine also, as the product from its action on turmerol contained about 15 per cent of chlorine. We have postponed the study of this substance for the present.

The formation of the turmerylchloride described above indicates that turmerol is an alcohol, and to confirm this view we next treated the turmerylchloride with various reagents, and found that its chlorine was removed, in part, at least, by boiling water or by alcoholic solutions of sodic acetate, potassic cyanide, or ammonia,—a substance being formed in each case with the characteristic smell of the class to which it should belong. The regenerated alcohol and the acetate we were unable to purify, while the nitrile and its corresponding acid and the amine were formed in very small quantities and did not give crystalline compounds, so that their further study, which we had at first hoped would establish the formula of turmerol, did not promise to repay the labor.

To still further confirm the alcoholic nature of turmerol, we prepared the sodium compound as follows, —

Action of Sodium on Turmerol.

Some of the turmerol mixed with high boiling ligroine was warmed with sodium in a flask with a return cooler for twelve hours, during which time hydrogen was given off; the liquid was then filtered, and the ligroine evaporated off from the viscous filtrate.

I. 0.1456 g. of substance gave 0.0374 g. of Na_2SO_4.
II. 0.9820 g. gave 0.2342 g. of Na_2SO_4.

	Calculated for $C_{19}H_{27}ONa$.	Found.	
		I.	II.
Sodium	7.82	8.32	7.72

The substance forms a viscous semi-solid mass.

Sodic hydrate seemed not to act upon turmerol.

An attempt to convert turmerol into its acetate by heating it with acetic anhydride and sodic acetate on the water-bath gave a product having the same smell as that from the reaction of sodic acetate on turmerylchloride, but no means could be found of separating it from the unaltered turmerol, as it was decomposed by distillation even *in vacuo.* We accordingly turned our attention to the ethers of turmerol, and selected for study the isobutylether, as the difference between the percentage composition of this and that of the alcohol would be greater than in the case of the methyl- or ethyl-ethers.

Isobutylether of Turmerol.

This body was prepared by boiling the sodium compound with isobutyliodide in a flask with a return-condenser for some time; the product was purified by distillation *in vacuo*.

I. 0.2110 g. of substance gave 0.6524 g. of CO_2 and 0.2039 g. of H_2O.

II. 0.2742 g. of substance gave 0.8520 g. of CO_2 and 0.2646 g. of H_2O.

	Calculated for $C_{19}H_{27}OC_4H_9$.	Found.	
		I.	II.
Carbon	84.14	84.45	84.71
Hydrogen	10.97	10.73	10.83

It is a heavy yellowish oil with a pleasant smell. The ethylether is a similar substance.

From the observations described there can be no doubt that turmerol is an alcohol.

Oxidation of Turmerol.

When turmerol was treated with a hot aqueous solution of potassic permanganate until it was no longer decolorized, and after destroying the slight excess of permanganate with sodic sulphite the liquid was filtered from the brown hydrate of manganese, upon adding sulphuric acid a yellowish-white precipitate was thrown down, which, purified by washing with alcohol, became perfectly white, and volatilized without melting, indicating that it was terephthalic acid. To prove that this was the case, the acid was converted into the methylester by passing hydrochloric acid through methylalcohol, in which it was suspended. The solid gradually dissolved, and upon allowing the alcohol to evaporate, long prisms were deposited, which, after two crystallizations from hot alcohol, melted at 139°–140°. Melting-point of methylester of terephthalic acid 140°. Another sample of the acid was analyzed, —

0.1782 g. of substance gave 0.3798 g. of CO_2 and 0.0641 of H_2O.

	Calculated for $C_8H_6O_4$.	Found.
Carbon	57.83	58.12
Hydrogen	3.62	4.00

The product in this case, therefore, is terephthalic acid, and turmerol must stand in close relationship to the para series of aromatic compounds. It is probably a derivative of the terpenes.

The formation of terephthalic acid from turmeric oil also explains the results of Ivanow-Gajewsky in regard to the oxidation of curcumin, as it renders it almost certain that the terephthalic acid obtained by him, but of which we could find no trace, proceeded from an impurity of turmeric oil in his curcumin.

When cold potassic permanganate not in excess is used, turmerol yields one or more apparently new acids, with the investigation of which we are at present occupied.

SUMMARY.

The formula of turmerol (the fraction of turmeric oil boiling from 193° to 198° under 60 mm. of pressure) is $C_{19}H_{28}O$, or one of its adjacent homologues.

Its alcoholic nature is proved by the following observations: —

1. Conversion into $C_{19}H_{27}Cl$ by hydrochloric acid or phosphorous trichloride. The chlorine can be removed by ordinary reagents.

2. The formation of a compound, $C_{19}H_{27}ONa$, by the action of sodium.

3. The formation of its isobutylether, $C_{19}H_{27}OC_4H_9$.

That it is related to the para compounds of the aromatic series is proved by its conversion into terephthalic acid by treatment with a hot aqueous solution of potassic permanganate in excess.

II.

OBSERVATIONS OF THE TRANSIT OF VENUS, DECEMBER 5 AND 6, 1882, MADE AT THE HARVARD COLLEGE OBSERVATORY.

By Edward C. Pickering.

Presented December 13th. 1882.

The chances of cloudy weather at this Observatory early in December are large, and Cambridge was not selected by the United States Commission on the Transit of Venus as a station for observations of the phenomenon. It therefore seemed injudicious to make any extensive preparations for the occasion. The available telescopes at the Observatory, however, were employed in observing the contacts. Photometric and spectroscopic observations were also obtained with the East Equatorial, and measurements of the diameter of Venus were made with the telescope of Mr. Chandler, mounted in the West Dome, and also with the East Equatorial.

The morning of the transit was so cloudy that there seemed little prospect of observing the contacts; but the sun gradually became visible, and the clouds were thin enough at the time of ingress to allow observation of both the first and the second contacts. The first part of the afternoon was nearly clear, and the third contact was well seen. A few minutes later the sun entered a mass of thin clouds, but was still sufficiently well seen for observation of the last contact.

Arrangements had been made before the day of the transit with the Western Union Telegraph Company for the distribution of the time signals of this Observatory among those who might desire to obtain them on December 6. The clock at which these signals originate was carefully compared with the standard sidereal clock of the Observatory at frequent intervals, and also with the signals furnished by the United States Naval Observatory at Washington, which were received here by telegraph. To determine the error of the sidereal clock, observations were made with the meridian circle by Professor W. A. Rogers, the results of which are given below. Since the transit, in order to remove any doubts with regard to the error of the sidereal clock as determined by a large fixed instrument, Professor Rogers has made a special series of observations, in which he used both the meridian circle and the portable transit instrument on each of eight evenings, determining the clock error independently with each instrument. The result confirms the correctness of the form of level employed with the meridian circle, and shows that the instrument furnishes trustworthy results for the absolute as well as the relative clock error. The mean correction to be applied to the error found by the meridian circle in order to reduce it to that found by the portable transit instrument, according to these observations, is $+0^{s}.08$; the eight separate results are $+0^{s}.20$, $+0^{s}.06$, $+0^{s}.09$, $+0^{s}.07$, $+0^{s}.06$, $+0^{s}.11$, $+0^{s}.09$, $+0^{s}.05$, the first having a weight of one third. As the magnifying powers and the reticules used with the two instruments differ materially, the amount of the correction is not surprising.

The results for the error of the sidereal clock obtained from the observations with the meridian circle near the time of the transit are exhibited in Table I. The first two columns contain the date of the observations in mean solar days and tenths, and the sidereal time, to hundredths of an hour, for which the error was determined. The third column gives the number of stars on which each result for clock error depends. The next two columns give the amount by which the clock was slow at the time of each set of observations, and the corresponding error for noon of December 6, corrected by means of the hourly rate $+0^{s}.023$. The last two columns contain the values of the instrumental constants n and b (angle at pole, and inclination of axis).

TABLE I.—Observed Clock Errors.

Date. 1882.	Sid. Time.	No. of Stars.	Clock Slow.		n	b
			Observed.	Red. to Dec. 6.0		
Dec. 4.2	$21^{h}.92$	5	$+2^{m}\ 21^{s}.25$	$+2^{m}\ 22^{s}.24$	$-1^{s}.10$	$+0^{s}.77$
Dec. 4.8	12.63	4	$+2\ \ 21.69$	$+2\ \ 22.46$	-1.03	$+0.77$
Dec. 5.4	3.07	4	$+2\ \ 22.05$	$+2\ \ 22.37$	-1.05	$+0.77$
Dec. 6.2	22.05	7	$+2\ \ 22.36$	$+2\ \ 22.24$	-1.05	$+0.77$

The mean result for noon of December 6 is $+2^{m}\ 22^{s}.33$. Reducing this to the result to be expected from the portable transit instrument, by adding $+0^{s}.08$ as above, we have $+2^{m}\ 22^{s}.41$, with an hourly increase of $+0^{s}.023$.

On December 5, 6, and 7, at noon, the Washington signals were received at Cambridge, and compared by chronograph with our sidereal clock. The result, after allowing for the difference in longitude, was that the Washington clock was fast $0^s.6$, $0^s.4$, and $0^s.3$ on the three days respectively. The signals were promised for December 4 also, but were not received, as the lines were occupied in transmitting political news. A good example is thus afforded of the importance of depending on the local observatories for supplying the public with time.

The clock distributing the mean-time signals from the Harvard College Observatory is kept as nearly as may be $15^s.5$ fast. The time is therefore that of the meridian passing through the State House in Boston, and $4^h\ 44^m\ 15^s.5$ west of Greenwich. On the day of the transit the deviation of the Washington signals was noted, and, to avoid the confusion arising from two systems, our signals were brought to an approximate agreement with them, rather than with our own determination of the local time. Frequent comparisons were made with our sidereal clock, and showed that at December 5.8 our signals were $0^s.6$ fast; at December 6.0, $0^s.5$ fast; at December 6.3, $0^s.5$ fast; and at December 6.8, $0^s.2$ fast. Allowing for the difference of longitude, these signals therefore did not differ more than a tenth of a second from the Washington signals, but to reduce them to the true time both should be regarded as about $0^s.5$ fast. In other words, in reducing to Greenwich mean time, the longitude for the Washington and Boston signals should be taken as $5^h\ 8^m\ 11^s.7$ and $4^h\ 44^m\ 15^s.0$ respectively. Since the observed times of contact are known to be liable to variations of several seconds, these corrections in any case are small, and may be neglected without serious error, especially as it is useless to give the resulting times of contact more closely than to single seconds.

CONTACTS.

A statement of the results of the contact observations is given below, in Table II. The upper part of the Table contains in successive columns the names of the observers and recorders, the apertures and focal lengths of the telescopes in centimeters, their magnifying powers in diameters, and the corrections required at ingress and at egress to reduce the observed times to Cambridge mean or sidereal time according to the timepiece employed. These corrections are given in accordance with the assumption that the signals furnished by the mean-time clock give the time of a meridian $4^h\ 44^m\ 15^s.5$ west of

Greenwich. The second part of the Table gives the observed times of the four contacts, without any corrections. The third part contains the concluded Greenwich mean times of the contacts noted by each

TABLE II. — CONTACTS.

Observer.	Recorder.	Aperture in cm.	Focal Length in cm.	Power in Diameters.	Corrections of Time-piece.
E. C. Pickering	A. W. Cutler	14.5	682.5	206	$+9^s.0$, $+10^s.3$
Arthur Searle	W. A. Rogers	13.2	230	220	$-76^s.2$
O. C. Wendell	A. W. Cutler	10.2	141.4	40, 90	$+9^s.0$, $+10^s.3$
J. R. Edmands	R. G. Saunders	10.2	140	150	$+82^s.3$, $+82^s.3$
S. C. Chandler, Jr.	W. V. Brown	15.2	244	180	$-26^s.8$, $-24^s.7$
W. H. Pickering	R. G. Saunders	6.4, 10.2	71, 84	20, 110	$+82^s.3$, $+82^s.3$

Observer.	Observed Times of Contacts.			
	I.	II.	III.	IV.
E. C. P.	$21^h\ 19^m\ 43^s.4$	$21^h\ 39^m\ 51^s.3$	$3^h\ 3^m\ 3^s.8$	$3^h\ 23^m\ 10^s.0$
A. S.	. . . . . .	. . . . . .	20 6 23.4	20 26 28
O. C. W.	21 20 8.2	. . . . . .	3 3 8.2	3 23 14.2
J. R. E.	. . . . . .	14 40 1	20 3 40	20 23 40
S. C. C.	21 20 22	21 40 30	3 3 30	3 24 10
W. H. P.	. . . . . .	14 40 9	20 3 33	20 24 0

Observer.	Greenwich Mean Time of Contacts.				Difference from Mean.			
	I.	II.	III.	IV.	I.	II.	III.	IV.
E. C. P.	$2^h\ 4^m\ 23^s$	$2^h\ 24^m\ 31^s$	$7^h\ 47^m\ 45^s$	$8^h\ 7^m\ 51^s$	-9^s	-12^s	$+5^s$	-1^s
A. S.	. . .	. . .	7 47 41	8 7 42	. . .	. . .	+1	—10
O. C. W.	2 4 48	. . .	7 47 49	8 7 55	+16	. . .	+9	+3
J. R. E.	. . .	2 24 50	7 47 36	8 7 33	. . .	+7	—4	—19
S. C. C.	2 4 26	2 24 34	7 47 36	8 8 16	—6	—9	—4	+24
W. H. P.	. . .	2 24 58	7 47 30	8 7 54	. . .	+15	—10	+2
Mean	2 4 32	2 24 43	7 47 40	8 7 52				

observer, obtained by adding $4^h\ 44^m\ 31^s$ to each of the Cambridge mean times. The mean result for each contact is given in the last line of the Table. At the right are given the differences of each observer's result from the mean of all.

The following notes contain, under the name of each observer, the details of his work.

E. C. Pickering.

The instrument employed was the East Equatorial. Its full aperture is 15 inches, which on this occasion was reduced to about 6 inches by a cap over the object-glass. An audible signal was given to the recorder at the time of each phenomenon noted. The recorder took the time of each signal from the chronometer, and recorded it, with any subsequent remarks by the observer. The wedge of shade glass placed between the eyepiece and the eye was of a greenish tint. In observing the first contact, the last time recorded before the appearance of the notch was $9^h\ 19^m\ 29^s.6$ by the chronometer. Venus was first seen at $9^h\ 19^m\ 44^s.2$ by the chronometer. The edge of the sun was wavy, rendering it difficult to decide whether an indentation was real. At $9^h\ 19^m\ 49^s.0$ the interval between the cusps was estimated at $9''$; two parallel lines $6''$ apart served as the unit of measure. From a reduction of this observation the time of first contact appears to be $9^h\ 19^m\ 42^s.6$; the mean of this and of the time directly observed is here assumed to be the time of the first contact, which is therefore $9^h\ 19^m\ 43^s.4$ by the chronometer. A scale in the eyepiece would allow the observer of phenomena like these to make estimates of the interval of the cusps without removing his eye from the telescope, and would accordingly afford him many of the advantages of a double-image micrometer without its disadvantages.

The images at the second contact were unusually well defined, and the contact was recorded as occurring at $9^h\ 39^m\ 51^s.3$. Eight seconds later it was clearly past.

The third contact was recorded as occurring at $3^h\ 3^m\ 3^s.8$. At $3^h\ 3^m\ 21^s.4$ the interval between the cusps was estimated as double that between the lines in the field, and consequently as $12''$. A reduction of this observation would make the time of contact $3^h\ 3^m\ 0^s.0$.

The fourth contact was recorded as occurring at $3^h\ 23^m\ 10^s.0$. At $3^h\ 23^m\ 3^s.4$ it had not occurred, at $3^h\ 23^m\ 19^s.4$ it was certainly past.

The chronometer used by the recorder, who also recorded for Mr.

Wendell, was Bliss & Creighton 1182; it is regulated to mean time, and has been in frequent use at the Observatory.

Arthur Searle.

The instrument was the five-inch telescope formerly mounted in the West Dome. As it was not provided with any stand, and as economy was an object kept strictly in view during the preparations for the transit, the best plan for using this telescope seemed to be to lay it horizontally upon a rough frame, at a height of three feet from the ground, before the south entrance of the Observatory. A plane mirror of unsilvered glass, formerly used in photographing the sun, was placed upon the block of stone at the east side of the steps of the entrance. This mirror was attached to the frame originally prepared for it, which is provided with screws for moving it approximately in altitude and in azimuth. The dimensions of the mirror are 7½ by 6 inches, so that the sunlight reflected from it at moderate hour angles was thrown upon the whole surface of the object-glass before it. The two surfaces of the mirror are inclined to each other, so that only one image of the sun is seen. In order to keep this image of the sun in the field, the services of an assistant were necessary. Unfortunately, the assistant who had accustomed himself before the transit to the management of the mirror, considering the morning too cloudy for any observation, did not arrive at the Observatory in season to take part in the observations at ingress. No other assistant having the necessary skill was available, and an attempt made to use the telescope at ingress was therefore unsuccessful.

At egress, the mirror was very successfully managed so as to keep the required part of the sun's limb in view, and Professor W. A. Rogers kindly undertook to record the times at which the observer gave his signals. The observation of the third contact was accordingly a satisfactory one. Nine seconds before the time recorded as that of the contact, the sun's limb became noticeably darkened at the place of egress, but the shade was lighter than the tint of the planet itself. The shade gradually darkened as the planet advanced, and at the time recorded as that of contact a darkness equal to that of the planet's disk had reached the limb of the sun. This phenomenon could not be distinguished from that of geometrical contact. If the limb of the sun had been steadier, it is possible that such a distinction might have been made. The image, in fact, was by no means bad, but there was sufficient undulation to make a very exact observation of geometrical contact impossible. Thirteen seconds after the recorded time it had become evident that the cusps were separated by a part of the planet's limb, and that geometrical contact was past.

These observations were made through a dark red shade-glass between the eyepiece and the eyestop. The limb of the sun was distinctly seen, and was free from glare. As the sun entered the thin clouds mentioned in the introductory remarks above, the red glass was replaced by a blue one, which admitted much more light. The part of the planet exterior to the limb of the sun was then certainly, though indistinctly, seen. Its outline seemed to be part of a smaller circle than that bounding the portion of the disk interior to the sun's limb. The increasing cloudiness soon put an end to this appearance, the Greenwich mean time of which, derived from the record, is $7^h\ 57^m\ 31^s$.

The fourth contact was observed with some difficulty, owing to the clouds and to the necessity of an occasional movement of the mirror to keep the image in the field. The time given is that of a signal accompanied by the remark "Notch doubtful"; the notch was not afterwards seen.

During the transit, the disk of the planet was uniformly dark, except that at times it seemed to be crossed by faint streaks of light, very likely due to slight defects in the shade-glass or other parts of the optical apparatus employed.

The eyepiece used was positive, No. 5 of the set of eyepieces belonging to the large filar micrometer of the East Equatorial, and, with that instrument, having a nominal magnifying power of 688. Its power, with the telescope used during the transit, has been determined by two methods, and the approximate mean result 220 is given in the Table.

The chronometer employed was Bond 236, regulated to sidereal time; it has been in constant use at the Observatory for many years.

O. C. Wendell.

The instrument employed was the finder of the East Equatorial. The object-glass was silvered to reduce the light, and an additional reduction was effected by a shade-glass. Between the first and second contacts the silvering was partially removed, owing to an apprehension that the clouds would grow thicker; but as the sky actually became clearer, the second contact could not be observed. Before the third contact, the film of silver was entirely removed, and the object-glass was smoked by Mr. Clacey's method, which sufficed, with the aid of one shade-glass, to reduce the light.

The first contact was well observed, but the recorder did not notice the signal, and the time is derived by estimate. According to the observer, the signal was given half-way between the last two signals of Professor Pickering, whose own estimate, however, placed it six seconds later. The mean of these estimates was adopted.

The third and fourth contacts were well seen and recorded. The time given for the third contact is that when the diminishing thread of light at the place of egress definitely broke. Eighteen seconds earlier contact had certainly not yet occurred.

Eight seconds previous to the time of fourth contact it was evident that the egress had not been completed.

J. R. Edmands.

The telescope was one borrowed from Dr. E. T. Caswell, of Providence, R. I., and originally owned by Dr. Alexis Caswell, of Brown University. It was attached to a portable equatorial mounting (without clock) belonging to the Observatory. The observations at ingress were made on the east balcony of the dome, and at egress on the west balcony. The eyepiece was negative, and the light was reduced by one shade-glass placed near the focus of this eyepiece at second contact, and by three shade-glasses, one on each side of the focus and one next the eye, at the third and fourth contacts.

The chronometer used in recording these observations, as well as for those of Mr. W. H. Pickering, was Frodsham 3451, regulated to sidereal time. This is an excellent instrument, of much value in the work of the Observatory Time Service.

At first contact the rapid changes in the opacity of the clouds prevented observation of the phenomenon, as the observer had no wedge of shade-glass, and could not readily control the brightness of the field. At second contact, the recorder found it impracticable to note the times from the signals of the two observers, and the assumed times are derived by estimate. The original estimate of the time of the signal "Past" was derived from an inspection of the chronometer made immediately after the observer learned that no record had been secured. But he was satisfied, on consideration, that this first estimate allowed too little for the interval between the signal and his inspection of the chronometer; besides which, his signal "Past" must have been given an appreciable time after the contact itself. His last signal, "Not yet," preceded the signal "Past" by about ten seconds. On these accounts, he estimated the observed time of contact, which has been entered in the Table, as five seconds earlier than the original estimate of the time of the signal "Past." This decision was made before correcting the result for error of chronometer, and before comparing it with any other observation.

At the third and fourth contacts, the recorder counted the seconds from the chronometer, and the observers recorded the times of their observations. At the third contact, the seeing was good, and the following note was made: "No black drop seen. Purposely used faint image." The clouds impeded any similar observation at the second contact. The telescope was somewhat disturbed by wind during the observations at egress, which prevented the observation of additional phenomena.

S. C. Chandler, Jr.

The first contact was looked for at a part of the limb estimated to be 3° to 5° to the right of the apparent vertex. The notch was suddenly noticed still nearer the apparent vertex at the time given as that of contact. Nineteen seconds later the notch had increased, confirming the first observation with regard to the place of ingress.

The time given as that of second contact is that of geometrical contact in the opinion of the observer. Seven seconds before the recorded time the contact had not occurred. Four seconds after the recorded time it was still uncertain whether the contact was past. Nine seconds after the recorded time the contact was certainly past. No "black drop" was seen.

Thirty-five seconds before the recorded time of third contact a shade appeared on the sun's limb, very much fainter than the disk of Venus. This shade increased in darkness, but did not seem to confuse the determination of the time of geometrical contact, which is that recorded for this phase of the transit. The recorded time must be as early as that of geometrical contact, which might possibly, however, have been thought to occur ten seconds later than the recorded time. Twenty-two seconds after the recorded time, contact was certainly past by several seconds.

The fourth contact was very satisfactorily observed. Eight seconds before the recorded time the notch was still certainly visible; at the recorded time it was certainly gone.

The telescope was one belonging to the observer, and lately placed on the equatorial mounting in the West Dome. No shade-glasses were used. The necessary reduction of the light was effected by previously smoking the front surface of the crown and the back surface of the flint lens of the object-glass. This was done by Mr. John Clacey, the maker of the telescope, and the result proved very satisfactory. A negative eyepiece was used in observing the contacts.

The timepiece used was the pocket-chronometer Patek, Phillipe, & Cie. 34,807.

W. H. Pickering.

The instrument selected for the observations was the Bowditch Comet-seeker; but as dew upon its reflecting prism prevented observations with it at ingress, the Quincy Comet-seeker, a smaller instrument, was employed in observing the second contact. No complete record of these observations was secured, owing to the circumstances explained in the notes relating to Mr. Edmands's observations. The estimate of the time of contact is based upon the circumstance that the observer's signal "Past" was given one second later than the corresponding signal by Mr. Edmands, according to the judgment of both observers. But on consideration, previous to any comparison with other observations, it appeared likely that this signal "Past" was given a little too early. The observer, therefore, assigned for his observation of contact a time three seconds later than the original estimate of Mr. Edmands for the time of his own signal.

The Bowditch Comet-seeker was used at egress.

Observers at other Stations.

The following observations of the transit have been communicated to me for publication, and are here inserted.

1. Station, the establishment of Messrs. Alvan Clark & Sons in Cambridgeport, Massachusetts. Approximate latitude, +42° 21′ 16″; approximate longitude, west of Greenwich, $4^h\ 44^m\ 26^s.7$. The times are given according to the clock signals of this Observatory.

Observer, Alvan G. Clark. Second contact, $21^h\ 40^m\ 3^s$; third, $3^h\ 2^m\ 30^s$ (the observer has no doubt that the minute should be 3 instead of 2); fourth, $3^h\ 23^m\ 54^s.5$.

Observer, C. A. R. Lundin. Third contact, $3^h\ 3^m\ 13^s$; fourth, $3^h\ 23^m\ 34^s$.

Reducing these observations to Greenwich mean time by the addition of $4^h\ 44^m\ 15^s.5$, we have, for Mr. Clark, $2^h\ 24^m\ 18^s$, $7^h\ 47^m\ 46^s$, $8^h\ 8^m\ 10^s$; and for Mr. Lundin, $7^h\ 47^m\ 28^s$, $8^h\ 7^m\ 50^s$.

2. Station, near St. Paul's Church, New York. Approximate latitude, +40° 46′.0; approximate longitude, west of Greenwich, $4^h\ 56^m\ 0^s$. Observer, Rev. G. M. Searle. Telescope by Dollond; aperture, 2.65 inches; focal length, 44 inches; magnifying power, 60.

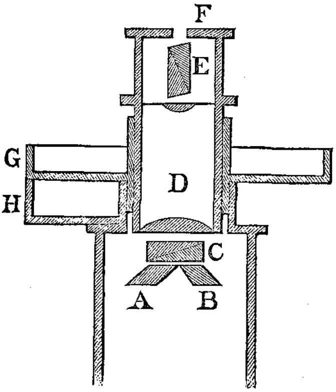
Timepiece, a good watch, the errors of which were determined by sextant observations at $22^h\ 16^m$, $22^h\ 34$, and $1^h\ 11^m$, which gave the respective corrections $+9^s$, $+8^s$, $+3^s$. No "black drop" was seen at either internal contact. The first contact was lost; the rest were observed as follows: $21^h\ 28^m\ 2^s$, $2^h\ 51^m\ 49^s$, $3^h\ 11^m\ 50^s$. The corrected mean times are $21^h\ 28^m\ 10^s$, $2^h\ 51^m\ 52^s$, $3^h\ 11^m\ 53^s$; and the corresponding Greenwich mean times are $2^h\ 24^m\ 10^s$, $7^h\ 47^m\ 52^s$, $8^h\ 7^m\ 53^s$. The sun's limb was remarkably steady at egress, but somewhat disturbed at ingress.

3. Station, terrace at No. 55 Habana Street, Havana, Cuba. Approximate latitude, $+23°\ 9'\ 21''$; approximate longitude, west of Greenwich, $5^h\ 29^m\ 26^s$. Observer, Professor Charles Hasselbrink (U. S. Signal Service observer in Havana). Telescope by Negretti and Zambra; aperture, 2.5 inches; focal length, 39 inches; magnifying power, 80. Chronometer Negus 582, slow 3^s, by comparisons furnished by the observatory of Don José Maria Garcia de Haro, semi-official observer for the Spanish Navy and the mercantile marine. The observer recorded for himself; the telescope was shaken by wind in the afternoon. The external contacts are considered doubtful, but the internal contacts were well observed. Observed times of contacts, $20^h\ 33^m\ 57^s$, $20^h\ 54^m\ 30^s$, $2^h\ 19^m\ 0^s$, $2^h\ 36^m\ 47^s$; corrected mean times, $20^h\ 34^m\ 0^s$, $20^h\ 54^m\ 33^s$, $2^h\ 19^m\ 3^s$, $2^h\ 36^m\ 50^s$; resulting Greenwich mean times, $2^h\ 3^m\ 26^s$, $2^h\ 23^m\ 59^s$, $7^h\ 48^m\ 29^s$, $8^h\ 6^m\ 16^s$.

Just before internal contact at ingress, the observer saw a fine line of light round the disk of Venus, beyond the limb of the sun. During the transit, a delicate aureola of very white light was noticed around the planet, suggesting the illumination of its atmosphere. Patches of a dark grayish tint were noticed at times upon the deep black disk of Venus.

Photometric Observations.

A photometer was constructed for comparing the brightness of the disk of Venus during transit with that of the sky in immediate proximity to the sun's limb. In the accompanying figure, *A* and *B* are two glass prisms, the first having parallel sides, the other with sides inclined at a small angle. *C* is a double-image prism, *D* a positive eyepiece, *E* a Nicol, and *F* an eyestop. A graduated circle, *G*, and an index, *H*, serve to measure the angle through which the eyepiece and Nicol are turned. The whole is inserted, like an eyepiece, in the tailpiece of the 15-inch telescope of the Observatory. The light from the object-glass, striking upon the prism *A*, is not deviated, but is divided by the prism



C into two pencils, one of which passes without deviation through the eyepiece and the hole in the eyestop to the eye. The other pencil is thrown to one side by *C*, and is cut off by the eyestop. The light passing through *B* is deviated about 6° by the difference in inclination of its two inclined sides. This light is also divided into two pencils by *C*, one retaining the deviation imparted by *B*, and being cut off by the eyestop. The other is deviated by *C*, but in such a manner as to counteract the inclination imparted to it by *B*. It therefore passes centrally through the hole in the eyestop to the eye of the observer. The latter accordingly receives two pencils of light formed by the same object-glass, one receiving the light from *A*, the other that from *B*. These two pencils are polarized by *C* in planes at right angles, and their relative brightness may accordingly be varied at will by turning the Nicol *E*. The instrument in principle closely resembles the meridian photometer for some years in use at this Observatory. The same device is employed to secure two equal pencils polarized in perpendicular planes, but in that instrument two equal object-glasses are employed, instead of two images of the same objective.

The eyepiece is focused on the front surface of the prisms *A*, *B*, so that their adjacent edges appear as a line dividing the field into two equal parts. By turning the Nicol the brightness of either part of the field may be reduced indefinitely, so that the brighter may always be brought to equality with the fainter. Placing the whole instrument at the principal focus of the telescope, we see side by side in the two halves of the field images of objects really about 16′ apart.

The observations were made by placing the edge of the prism parallel to the sun's limb at the point nearest Venus, and bringing Venus into one half of the field. A portion of the sun's disk near its centre will be seen in the other half of this field, and may be compared directly with Venus by turning the Nicol. Settings were made in the four positions of the Nicol in which the images appeared equal, and the positions read to tenths of a degree. The observation was then repeated, moving the telescope so that the portion of the sky close to the sun's limb should be measured in the same manner. Eight settings taken in this way constitute a set, and give the relative light of the sky and Venus. To eliminate any difference in the prisms the photometer was rotated 180° after each set, but no perceptible difference is indicated in this way. To reduce the observations, the first reading was subtracted from the second, and the third from the fourth. Calling the sum of these differences A, the relative light, $L = \tan^2 \frac{1}{4} A$. It will also be convenient to use a method of expressing the light in stellar magnitudes, according to the method already used in this Observatory for comparing nebulæ and portions of the moon. When surfaces are thus compared, portions of equal area are selected and reduced to stellar magnitudes by the formula of Pogson. We shall then have the difference in magnitude, $M = 2.5 \log L$. In Table III. the successive columns give a current number, the Cambridge mean time, the difference in light of equal areas of Venus and the sun expressed in stellar magnitudes, the corresponding quantities for the sky near the edge of the sun, and these same ratios expressed in percentages, that is, assuming the light of the centre of the sun equal to one hundred. The last column gives the initial of the observer.

TABLE III. — PHOTOMETRIC OBSERVATIONS.

No.	Cambridge Mean Time.	Difference in Magnitude.		Percentages.		Observer.
		Venus.	Sky.	Venus.	Sky.	
1	$1^h\ 7^m.6$	4.30	2.54	1.9	9.6	W.
2	1 18.4	4.55	2.94	1.5	6.7	W.
3	1 24.8	4.05	2.79	2.4	7.7	W.
4	1 29.4	4.46	2.40	1.6	11.0	W.
5	2 48.3	5.58	3.32	0.6	4.7	P.
6	2 51.6	4.44	2.74	1.7	8.0	P.
7	2 54.4	4.37	3.06	1.8	6.0	P.
8	Mean W.	4.34	2.67	1.8	8.8	W.
9	Mean P.	4.80	3.04	1.4	6.2	P.
10	Mean W., P.	4.57	2.85	1.6	7.5	Both.

The result for the light of the sky in the first line of the table depends upon eight settings.

These observations show a well-defined increase in light of the sky near the edge of the sun as compared with that received from Venus. This effect also seemed to me to be very perceptible without the photometer. To confirm it, I asked Mr. Wendell which looked to him the brighter. He satisfied himself that Venus certainly appeared darker than the sky. A slight difference was to be expected, since there are instances on record of the visibility of Venus before first contact. In the interval between the exterior and interior contacts, the edge of the planet has sometimes been traced beyond the limb of the sun. The effect was noticed by Mr. Searle shortly after the third contact, as above stated. According to his recollection of the appearance of the field, the difference in darkness beween the planet's disk and the sky was obvious, and might have been expected to make the planet more distinctly visible outside of the sun's limb than was actually the case.

No appreciable light could be received from Venus itself, unless that planet is incandescent or phosphorescent, an extremely improbable hypothesis. Doubtless the greater portion of the light, like that of the sky near the sun, is due to reflection of the light of the sun from the particles of the earth's atmosphere. During a total solar eclipse the interposition of the moon suffices to cut off nearly all the light near the sun, except the small portion due to the solar corona. It is therefore obvious that the light of the sky near the sun originates at no great distance from the earth, and is doubtless caused by reflection in the terrestrial atmosphere. In a communication to this Academy nine years ago (*Proceedings*, IX. 1), I showed that many of the phenomena of atmospheric illumination and polarization could be explained by specular reflection from the particles of the air, whose index of refraction differs very slightly from unity. In this case, if the sun was reduced to a point, the light of the sky at small distances would vary inversely as the fourth power of the distance. In any case, a glance towards the sun is sufficient to show that the light increases very rapidly as we approach the sun's limb. We should expect that the light of the portion of the atmosphere between us and the sun would be much greater than that outside of the sun's disk. Most of the light would be received from the portion of the sun at a very small angular distance. A point between us and the sun would be illuminated in all directions, that is, through the entire 360°. A point outside the sun's disk could at most receive light only from 180°. Moreover, the edge of the sun is much fainter than its centre, which would still farther reduce the light. We should then expect that the light received from Venus would be greater than that of the sky near the sun's limb, the opposite result from that indicated by the observations. This effect would be modified by the solar atmosphere, which would increase the light outside of the sun. The observations of Professor Langley, however, during the eclipse of 1878, seem to prove that the light of the corona is entirely insufficient to produce this effect. The difficulty of photographing the corona confirms this view, but its spectrum indicates that it is composed of light of a wave-length to which the photographic plate is not very sensitive.

An important source of error arises in almost all these measures from the diffuse reflection from dust or scratches on the object-glass. The effect of this would be similar to an increased haziness of the sky, and would tend to increase the apparent light received both from Venus and the sky. In our measures this effect was reduced to a minimum, as the object-glass had been cleaned shortly before the transit, and the diffuse reflection was therefore very slight. A remedy for this difficulty would be found by removing the object-glass and substituting for it a minute hole. When the sky is hazy we should expect an increased relative brightness near the edge of the sun. This may account for the larger readings obtained by Mr. Wendell, as the sky was somewhat clearer during my observations than during his. As the portion of the sky observed was only about 1′ distant from Venus, irregular clouds could not produce the observed difference in light. In fact, the persistence of the phenomena under varying conditions seems to leave little doubt that the disk of Venus was really much darker than the sky near it.

The solution of this problem would be greatly aided by researches of the kind described below, a portion of which will probably be undertaken at this Observatory. Measurement of the relative light of different portions of the sun's disk and of the sky at various distances from it. Measures of the sky at various distances from the moon, thus eliminating any effect corresponding to that of a solar atmosphere. Measures of the light of the disk of the moon during the progress of a partial eclipse of the sun.

Spectroscopic Observations.

The spectrum of the light received from Venus was observed with a star spectroscope constructed by Hilger. The dispersion was such that about one third of the spectrum was visible in the field of view at a time. Two prisms of dense flint glass were employed. This spectroscope was attached to the large Equatorial, and was focused on the limb of the sun. When Venus was brought upon the slit it appeared as a broad band traversing the spectrum lengthwise, which could be compared directly with the solar spectrum on each side of it. The slit was then brought tangential to the limb of Venus, so as to receive the light grazing its surface. The breadth of the dark band was thus reduced and flickered owing to the slight unsteadiness of the atmosphere. No difference in the spectrum was detected either by myself or by Mr. W. H. Pickering after careful examination.

This negative result should not be regarded as throwing doubt on the positive results attained by so skilful an observer as Professor Young, who is said to have detected the presence of aqueous vapor in Venus. I have not yet seen the details of his observation, but his facilities for making this observation were much greater than mine, and he probably used a much higher dispersion. I satisfied myself that there were no very marked absorption bands, and doubtless the phenomenon is one which requires more careful preparation than we were permitted to make without interfering with the other portions of our programme to which, in preparing our plans, we had attached more importance.

DIAMETER OF VENUS.

The measurements of the diameter of Venus, mentioned in the first paragraph of this communication, were made by Professor William A. Rogers and by Mr. S. C. Chandler, Jr. The subjoined reports from these gentlemen furnish the account of the work undertaken. In these reports, Mr. Chandler's telescope, mounted in the West Dome, has been called the West Equatorial.

Report by William A. Rogers.

The following method for the determination of the diameter of a planet was first employed by the writer in 1877, having been used in the determination of the diameter of Mars.

Let: —

x_0 = a line ruled upon glass and set in the direction of diurnal motion.
x_1 = a line ruled at a given angle, i, with respect to x_0, and reckoned from east to west.
x_2 = a line ruled at the angle $(180° - i)$ with respect to x_0.
y = a line ruled at right angles to x_0 and bisecting the angle formed between x_1 and x_2.
τ_1 = the observed time of transit of the preceding limb of the planet over x_1.
τ_2 = the time of transit of the following limb over x_1.
τ_3, τ_4 = the corresponding times over x_2.
D = the diameter of the planet.

Then:

$$D = 15 \cos \delta \, (\tau_2 - \tau_1) \sin i = 15 \cos \delta \, (\tau_4 - \tau_3) \sin i$$

For any variation whatever of the angle i we have:

$$\Delta i = \frac{D}{15 \cos \delta \, (\tau_2 - \tau_1) \cos i}$$

and hence, from transits over the line x_1,

$$D = 15 \cos \delta \, (\tau_2 - \tau_1) \sin \, (i + \Delta i)$$

$$= 15 \cos \delta \, (\tau_2 - \tau_1) \sin \left[i + \frac{D}{15 \cos \delta \, (\tau_2 - \tau_1) \cos i} \right]$$

and from the transits over the line x_2,

$$D = 15 \cos \delta \, (\tau_4 - \tau_3) \sin \left[i - \frac{D}{15 \cos \delta \, (\tau_4 - \tau_3) \cos i} \right]$$

If therefore the times of transit of each limb are taken over the lines x_1 and x_2, any error in D due to an erroneously assumed position angle will be eliminated.

It must be noted, however, that any error in Δi arising from an unknown error in the angles between x_0, x_1, and x_2 will be only partially eliminated. Designating by i and i' the angles which x_1 and x_2 make with x_0, and their variations on account of errors of graduation by Δi and $\Delta i'$ respectively, we have, from transits over x_1,

$$D = 15 \cos \delta \, (\tau_2 - \tau_1) \, [\sin i + \cos i \, \Delta i]$$

and from the transits over x_2,

$$D = 15 \cos \delta \, (\tau_4 - \tau_3) \, [\sin i' + \cos i' \, \Delta i']$$

or, since $i' = 180° - i$ nearly,

$$D = 15 \cos \delta \, (\tau_4 - \tau_3) \, [\sin i - \cos i \, \Delta i']$$

whence

$$D = \tfrac{15}{2} \cos \delta \, \big[[(\tau_2 - \tau_1) + (\tau_4 - \tau_3)] \sin i + \cos i \, [(\tau_2 - \tau_1) \, \Delta i - (\tau_4 - \tau_3) \, \Delta i'] \big]$$

The only case, therefore, in which the elimination will take place is that in which

$$(\tau_2 - \tau_1) \, \Delta i = (\tau_4 - \tau_3) \, \Delta i'$$

But since, on Dec. 6, the time required for Venus to make a complete transit over a line having $i = 20°$ was only 24^s, the effect of any small error in the graduation will be practically insensible.

For the equatorial diameter we have:

$$D = 15 \cos \delta \, (\tau_2 - \tau_1) \sin \, (90° + \Delta i)$$

Unless Δi, therefore, is very large, we shall have:

$$D = 15 \cos \delta \, (\tau_2 - \tau_1)$$

Assuming the same constant of differential refraction for Venus north and for Venus south, any error in the observed value of D

due to the differential refraction R_{rf} will be eliminated if we combine the observations over x_1 and x_2 with corresponding observations over these lines extended below the line x_0. Designating the times of transit for Venus north of x_0 by τ'_1, τ'_2, τ'_3, and τ'_4, we shall have:

For Venus South.

$$D = \tfrac{15}{2} \cos\delta \left[(\tau_2 - \tau_1) \sin\left(i + \frac{D}{15 \cos\delta\, (\tau_2 - \tau_1) \cos i} \right) + \right.$$

$$\left. (\tau_4 - \tau_3) \sin\left(i - \frac{D}{15 \cos\delta\, (\tau_4 - \tau_3) \cos i} \right) \right] + R_{\mathrm{rf}}$$

For Venus North.

$$D = \tfrac{15}{2} \cos\delta \left[(\tau_2 - \tau_1) \sin\left(i + \frac{D}{15 \cos\delta\, (\tau'_2 - \tau'_1) \cos i} \right) + \right.$$

$$\left. (\tau_4 - \tau_3) \sin\left(i - \frac{D}{15 \cos\delta\, (\tau'_4 - \tau'_3) \cos i} \right) \right] - R_{\mathrm{rf}}$$

Combining these equations, we shall still have, for any case except where Δi is due to an error in the assumed value of i, an equation of the form:

$$D = 15 \cos\delta\, (\tau_2 - \tau_1) \sin i$$

Two ruled plates were prepared for the observation of Dec. 6, one for the East Equatorial and one for the West Equatorial. They consist of one horizontal line, two vertical lines, and a series of lines having the inclinations 10°, 20°, 30°, 40°, 45°, and the inclinations 135°, 140°, 150°, 160°, and 170°, respectively, to the horizontal line. These lines were all extended below the line x_0, giving the angles 225°, 230°, 240°, 250°, 260°, and the angles 315°, 320°, 330°, 340°, and 350°.

In general, a complete series of observations consists of 10 transits over each of the inclined lines, and 20 transits over the vertical lines, both for Venus *south* and for Venus *north* of the horizontal line.

The results for Dec. 6, arranged in the order of the times of observation are as follows.

TABLE IV. — EAST EQUATORIAL.

Position of Venus with respect to horizontal line.	$i = 30°$		$i = 45°$		$i = 90°$		Remarks.
	D.	No. Obs.	*D.*	No. Obs.	*D.*	No. Obs.	
South.	62″.51	18	62″.46	18	60″.45	32	Seeing fair.
South.	62.27	20	60.85	20	59.62	40	Seeing fair. New zero of position.
North.	59.73	22	60.26	22	60.18	42	Seeing very bad.
South.	59.21	22	58.98	22	58.37	44	Image of Venus boiling. Reject.

TABLE V. — WEST EQUATORIAL.

Position of Venus.	$i = 10°$		$i = 20°$		$i = 30°$		$i = 45°$		$i = 90°$		Remarks.
	D.	No. Obs.	*D.*	No. Obs.	*D.*	No. Obs.	*D.*	No. Obs.	*D.*	No. Obs.	
	″		″		″		″		″		
South.	....	....	61.18	24	60.73	24	61.04	22	60.18	44	Seeing very good.
South.	....	....	61.37	20	60.94	20	61.43	20	60.59	40	Seeing fair. New zero.
North.	....	....	59.52	22	60.53	22	59.28	22	59.35	44	Seeing unsteady.
South.	60.56	22	....	....	....	....	....	....	61.70	44	Seeing fair.
North.	56.51	22	....	....	....	....	....	....	59.62	44	Seeing bad.

Collecting the results for each instrument, but rejecting the last series with the East Equatorial, we have:

TABLE VI.

Instrument.	$i = 10°$	$i = 20°$	$i = 30°$	$i = 45°$	$i = 90°$
	″	″	″	″	″
East Equatorial	....	....	62.51	62.46	60.45
	....	....	62.27	60.85	59.62
	....	....	59.73	60.26	60.18
Means	....	....	61.50	61.19	60.08
West Equatorial	....	61.18	60.73	61.04	60.18
	....	61.37	60.94	61.43	60.59
	....	59.52	60.53	59.28	59.35
	60.56	....	....	....	61.70
	56.51	....	....	....	59.62
Means	58.54	60.69	60.73	60.58	60.29

Combining the results of the observations over the inclined lines, and assigning the same weight for each value of *i*, we have:

TABLE VII.

	D for $i = 90°$	*D* for $i = 10° \ldots 45°$
	″	″
From the East Equatorial . . .	60.08	61.34
From the West Equatorial . . .	60.29	60.28
Means	60.18	60.81
	″	″
Values of *D* at the distance unity	15.92	16.09

It will be seen, by an examination of Tables IV. and V. that the magnitude of *D* apparently depends to a certain extent upon the character of the atmospheric conditions under which the observations were made. Arranging the results according to the character of the seeing, we have:

TABLE VIII. — SEEING FAIR TO GOOD.

Instrument.	$i = 10°$	$i = 20°$	$i = 30°$	$i = 45°$	$i = 90°$
	″	″	″	″	″
East Equatorial	....	....	62.51	62.46	60.45
	....	....	62.27	60.85	59.62
West Equatorial	....	61.18	60.73	61.04	60.18
	....	61.37	60.94	61.43	60.59
	60.56	....	....	....	61.70
Means	60.56	61.27	61.61	61.45	60.51
SEEING BAD TO VERY BAD.					
East Equatorial	....	....	59.73	60.26	60.18
	....	....	59.21	59.98	58.37
West Equatorial	....	59.52	60.53	59.28	59.35
	56.51	....	....	....	59.62
Means	56.51	59.52	59.82	59.84	59.38

Combining by weights proportional to the number of observations, we have:

TABLE IX.

	D for $i = 90°$	D for $i = 10° \ldots 45°$
For seeing fair to good . .	60.51″	61.39″
For seeing bad to very bad	59.38	59.38

From the observations made under favorable conditions, we have for the distance unity:

D for $i = 90°$	D for $i = 10° \ldots . 45°$
16″.01	16″.24

There is a general tendency of the observations to indicate a lesser value for the equatorial diameter, but the method of obtaining this quantity by direct transits over a vertical line is not a very reliable one. The apparent difference, therefore, between the diameter determined at different angles of inclination, is probably fictitious rather than real.

In order to determine the difference in the amount of the irradiation of a dark disk upon a bright ground and of a bright disk upon a darker ground, observations for the diameter were continued for several days succeeding the transit. Since it was only possible to observe both points of tangency of the inclined lines with the disk of the planet on one side of the vertical lines, the elimination of the effect of an error in the position angle of the line x_0 does not here take place. Care was taken, however, to make the setting for the zero of position as exact as possible.

The following results were obtained.

TABLE X.

Date.	Instrument.	$i = 10°$	$i = 20°$	$i = 30°$	$i = 40°$	$i = 45°$	Means.
1882.		″	″	″	″	″	″
Dec. 13–14	E. Equatorial	....	....	16.75	16.45	16.49	16.56
Dec. 14–15		....	....	16.66	16.58	16.14	16.46
Dec. 24–25		....	....	16.90	17.33	....	17.12
Dec. 26–27		....	17.96	17.66	17.47	17.29	17.47
1883.							
Jan. 1–2	West Equatorial	17.73	....	....	....	....	17.73

If these observations can be trusted we may conclude: —

(*a.*) That the difference in the value of the diameter at the distance unity, due to irradiation on Dec. 6, and on the days immediately following, is not far from 0″.4.

(*b.*) That up to a certain point this difference increases with the angular increase in the distance of the planet from the sun. This increase, however, is probably not quite as great as the observations seem to indicate. On Dec. 26 and Jan. 1 the atmospheric conditions were not favorable to good observations.

Report by S. C. Chandler, Jr.

The following determinations of the diameter of Venus during the transit on Dec. 6, 1882, were made by Professor Rogers's plan of transits over inclined lines, with the West Equatorial. The telescope had been prepared for solar observation by the maker, Mr. John Clacey, by smoking the front of the crown and the back of the flint lens of the object-glass; a process which he finds affords a better effect than a silver film, the image being sharper and the effect of contrast with the sky more agreeable. The result in the present instance was completely satisfactory. The obscuration produced by the double smoke film was sufficient to render a shade glass unnecessary with the power used, which was about 180 diameters.

The scheme of observation, and the plate, were the same as used by Professor Rogers. The transits were taken in sets consisting of an equal number of contacts of both limbs with lines ruled at equal and contrary angles with the middle transit lines, thus eliminating the error of the zero of position. The formula of reduction follows simply from equation (2) hereafter given. Thus, if we call Δt_1, Δt_2, the differences of the observed times of transit of opposite limbs, for the angles p and $-p$, respectively, we get

$$D = \tfrac{15}{2} \cos \delta \cos p \, (\Delta t_1 + \Delta t_2).$$

The corrections for proper motion and differential refraction are so far within the uncertainty of observation, in their effect on the concluded diameter, that they have been neglected. Table XI. gives the value of the observed diameter and the number of observations in each pair of sets arranged according to the position angle of the lines employed. Table XII. gives the means, taken with reference to the number of observations, of the results of Table XI.

TABLE XI.

$p = 80°$		$p = 70°$		$p = 60°$		$p = 50°$		$p = 45°$		$p = 0°$	
59″.66	6	61″.61	17	62″.07	6	63″.73	6	62″.47	6	61″.50	6
62.36	6	59.17	4	61.03	6			61.28	6	61.13	6
		60.87	6	61.30	6			63.11	6	61.03	6
				62.76	6			62.76	6	61.03	17
				61.06	17			62.18	17	61.03	4
				60.67	4			62.51	4	59.91	6
										61.23	6
										61.64	8

TABLE XII.

Position Angle of Lines.	Observed Diameter.	No of Observations.	Diameter reduced to Mean Distance.
80°	61″.01	12	16″.14
70°	61.09	27	16.16
60°	61.41	45	16.24
50°	63.73	6	16.85
45°	62.33	45	16.49
0°	62.09	59	16.42
Mean	61.83	194	16.35

The mean value of the diameter from the 194 observations is,

$$D = 16''.35.$$

It is noteworthy that the results over the different lines, with the exception of that at 50°, which is based on only 6 observations, all give values less than that of 16″.61, adopted in the Berlin Jahrbuch, Nautical Almanac, and Connaissance des Temps, and that the lines of greatest position angle, which by this method would be expected to afford the most accurate results, give the smallest values of the series.

It appears to me that the method of Professor Rogers is not limited, in its application to the interior planets, to their transits over the sun's disk, or to times when the conditions permit the whole disk to be seen; but that it may, by an appropriate construction of the plate and arrangement of the observations, be employed at any time when they are near inferior conjunction, and that determinations both before and after conjunction will eliminate any errors peculiar to each elongation.

Let p be the position angle, counted from an assumed zero, of a line on the plate drawn from some point taken as a centre; the *true* position angle being $p + \Delta p$. Let D and δ be the diameter and declination of the planet; $\Delta\delta$ the difference of declination from the centre of the plate when it passes north, and $\Delta'\delta$ when it passes south of that centre; and t and t', the corresponding observed times when the planet's limb in its diurnal motion is tangent to the line. Then in the triangle formed by the planet's centre, the intersection of its path with the line, and the observed point of tangency, the distance between the first two points is,

$$\tfrac{1}{2}D \sec(p + \Delta p) = \tfrac{1}{2}D \sec p + \tfrac{1}{2}D \tan p \sec p \,\Delta p$$

where, Δp being small, the terms involving its squares are neglected.

If we imagine a line drawn from the centre of the plate at the angle p from the true position zero, we have, from the triangle formed by the actual and imaginary lines and the portion of the path of the planet's centre between them, the length of the intercepted path:

$$\Delta\delta \,\Delta p \sec p \sec(p + \Delta p) = \Delta\delta \,\Delta p \sec^2 p$$

If now we call T the time when the centre of the planet is on this imaginary line when the planet passes north, and T' the time for a corresponding position when the planet passes south of the centre, we have the general equations:

$$T = t + \frac{1}{15 \cos\delta}\left[\pm \tfrac{1}{2}D \sec p \pm \tfrac{1}{2}D \tan p \sec p \,\Delta p + \Delta\delta \sec^2 p \,\Delta p\right]$$

(1)

$$T' = t' + \frac{1}{15 \cos\delta}\left[\mp \tfrac{1}{2}D \sec p \mp \tfrac{1}{2}D \tan p \sec p \,\Delta p + \Delta'\delta \sec^2 p \,\Delta p\right]$$

p being reckoned as usual from 0° to 360° in the direction n. f. s. p.; the upper sign being used for the preceding, and the lower sign for the following limb.

Let t_1 and t_2 be the observed times when the planet, passing north of the centre, has either limb tangent to lines at the angles p and $-p$ from the assumed zero. Then the 1st equation of (1) gives:

$$T_1 = t_1 + \frac{1}{15\cos\delta}\left[\pm \tfrac{1}{2}D\sec p \pm \tfrac{1}{2}D\tan p\sec p\,\Delta p + \Delta\delta\sec^2 p\,\Delta p\right]$$

(2)

$$T_2 = t_2 + \frac{1}{15\cos\delta}\left[\pm \tfrac{1}{2}D\sec p \mp \tfrac{1}{2}D\tan p\sec p\,\Delta p + \Delta\delta\sec^2 p\,\Delta p\right]$$

If t_0 be the corresponding time for a third line drawn through the intersection of the other two and bisecting the angle between them, we shall have $p = 0$, and

$$(3) \qquad T_0 = t_0 + \frac{1}{15\cos\delta}\left[\pm \tfrac{1}{2}D + \Delta\delta\,\Delta p\right]$$

But we have $T_2 - T_0 = T_0 - T_1$. Hence, putting $\tau = t_2 + t_1 - 2\,t_0$, and noting that $(1 - \cos p)\sec p = \tan p \tan \tfrac{1}{2}p$,

$$(4) \qquad \mp \tfrac{1}{2}D\tan p\tan\tfrac{1}{2}p - \Delta\delta\tan^2 p\,\Delta p = \tfrac{15}{2}\,\tau\cos\delta$$

In a similar way, when the planet passes south of centre, we get

$$(5) \qquad \mp \tfrac{1}{2}D\tan p\tan\tfrac{1}{2}p - \Delta'\delta\tan^2 p\,\Delta p = \tfrac{15}{2}\,\tau'\cos\delta$$

The addition of (4) and (5) gives,

$$(6) \quad D = \mp\cot\tfrac{1}{2}p\,[\tfrac{15}{2}\cos\delta\,(\tau + \tau')\cot p + (\Delta\delta + \Delta'\delta)\tan p\,\Delta p];$$

and their difference,

$$(7) \qquad \Delta p = \tfrac{15}{2}\cos\delta\,(\tau' - \tau)\,\frac{\cot^2 p}{\Delta\delta - \Delta'\delta}$$

But we have also, putting $r = t_2 - t_1$, and $r' = t'_2 - t'_1$,

$$(8) \qquad \begin{aligned} \Delta\delta &= \tfrac{15}{2}\,r\cos\delta\cot p - \tfrac{1}{2}D\,\Delta p\sec p \\ \Delta'\delta &= -\tfrac{15}{2}\,r'\cos\delta\cot p - \tfrac{1}{2}D\,\Delta p\sec p \end{aligned}$$

whence

$$\begin{aligned} \Delta\delta + \Delta'\delta &= \tfrac{15}{2}\,(r - r')\cos\delta\cot p \ \text{(nearly)} \\ \Delta\delta - \Delta'\delta &= \tfrac{15}{2}\,(r + r')\cos\delta\cot p \end{aligned}$$

which substituted in (6) and (7) give finally,

$$(9) \quad D = \mp\tfrac{15}{2}\cos\delta\cot p\cot\tfrac{1}{2}p\left[\tau + \tau' - (\tau - \tau')\,\frac{r - r'}{r + r'}\right]$$

$$(10) \qquad \Delta p = \frac{\tau' - \tau}{r + r'}\cot p$$

The last term in equation (9) disappears when the planet passes at equal distances north and south, and in general is inappreciable except when the error of position zero is large, or when the planet passes at very unequal distances north or south of the centre, which in practice need never occur.

Equation (9) consequently permits the determination of the diameter by observations on one limb only. As has been remarked, observations on the preceding limb before inferior conjunction, and on the following limb after it, may be expected to eliminate errors peculiar to the elongation.

It should be remarked that the quantity cot p cot $\frac{1}{2}$ p becomes unity for $p = 60°$, and for larger angles rapidly increases. In general the advantageous application of the method requires the use of lines at greater position angles than 60°.

In what precedes it has been assumed that the line corresponding to the time t_0 bisects the angle formed by the others, and also passes through their intersection. In ruling the plates for the observations of the diameter during the transit of Venus, these conditions may possibly not have been exactly fulfilled; since, as they did not affect the observations then contemplated, Professor Rogers did not especially attend to those points in the preparation of the plates. Any such errors may, however, be eliminated. Thus, if we put $a =$ the distance between the transit line on the plate from an imaginary line parallel to it passing through the point of intersection of the inclined lines, and Δi the inclination to a line bisecting the angle of the inclined lines, equation (3) becomes,

$$T_0 = t_0 + \frac{1}{15 \cos \delta} \left[\pm \tfrac{1}{2} D + \Delta\delta \ (\Delta p + \Delta i) + a \right]$$

and equation (9),

$$D = \mp \tfrac{15}{2} \cos \delta \cot p \cot \tfrac{1}{2} p \left[\tau + \tau' - 2\, a - 2\, (\Delta\delta - \Delta'\delta)\, \Delta i \right.$$
$$\left. + \frac{r - r'}{r + r'} (\tau' - \tau) \right]$$

Since Δi changes sign by turning the plate 180° in position angle, and a changes sign by turning the other side of the plate toward the eye these sources of error may be determined or eliminated by arranging the observations with appropriate reversals.

To exemplify partially the use of this method, I avail myself of some observations of the following limb of Venus, on various days succeeding the recent transit, by Professor Rogers and myself. As these were not arranged with a view to eliminate the possible errors involved in a and Δi, as it is the intention to do in the future, the results cannot be considered as having other than an illustrative value. The angle, 60°, was less than should properly be used for advantageous results, and the record gives no means of knowing in which series the plate was in the direct, and in which it was in the reversed position. The results are as follows.

TABLE XIII.

Date.	Number of Observations.	Diameter.	Observer.
1882		″	
Dec. 13–14	25	16.39	W. A. R.
" 14–15	20	17.06	"
" 24–25	22	17.58	"
" "	21	18.30	S. C. C.
" 26–27	17	17.89	"

These results are of interest for comparison with those obtained on the same days by Professor Rogers from different observations. The series is not sufficient to determine the "irradiation constant."

In conclusion, the results may be summarized as follows:—

1. Observations of the four contacts by six observers.

2. The determination, by a photometer especially devised for the purpose, of the relative amounts of light received from the disk of Venus, from the sky near the sun's edge, and from the sun's centre. Denoting the last amount by 100.0, that received from Venus was 1.6, and that received from the sky 7.5. Contrary to expectation, Venus was thus shown to be distinctly darker than the adjacent sky, and this result was confirmed by direct observation.

3. The spectroscopic observations. These gave negative results, and showed that no marked absorption was caused by the atmosphere of Venus.

4. A careful determination of the diameter of Venus by a method not previously attempted, and the suggestion of an application of this method to planets when both limbs cannot be observed. The result obtained by Professor Rogers was 16″.10 from transits over inclined lines, and that obtained by Mr. Chandler was 16″.35, which would be reduced 0″.02 by using only the transits over inclined lines.

III.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.*

1. ON CERTAIN SUBSTITUTED ACRYLIC AND PROPIONIC ACIDS.

By C. F. Mabery and F. C. Robinson.

Presented January 10th, 1883.

β-DIBROMACRYLIC acid, unlike the isomeric α-acid, will not unite with bromine at ordinary temperatures. After standing twelve days, a solution of the acid with bromine in chloroform was not bleached, and by slow evaporation of the solution crystals were deposited which melted at 86°, the melting-point of dibromacrylic acid. At 100° the addition of bromine was easily accomplished. When pure dibromacrylic acid was heated in a closed tube with undiluted bromine in slight excess over the calculated amount for one or two hours, tetrabrompropionic acid was formed in nearly the theoretical quantity. The excess of bromine was removed by evaporation from the crude product, which was purified by pressure in filter-paper and crystallization from carbonic disulphide and chloroform. From a concentrated solution in carbonic disulphide it crystallizes by slow evaporation in oblique prisms. It is somewhat soluble in hot water, from which it separates at first as an oil; but on further cooling it crystallizes in thick prisms. On boiling an aqueous solution of the acid, it is rapidly decomposed, imparting a milky appearance to the solution, probably from the formation of tribromethylen. Melting point 118°–120°. Its composition was determined by the following analyses.

I. 0.2149 grm. of the substance gave by Carius's method 0.4169 grm. AgBr.
II. 0.1639 grm. of the substance gave 0.3145 grm. AgBr.
III. 0.8899 grm. of the substance gave 0.2857 grm. CO_2 and 0.0478 grm. H_2O.

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* This work was done in connection with the summer course of instruction in chemistry for 1882. — C. F. M.

	Calculated for $C_3H_2Br_4O_2$.	Found.		
		I.	II.	III.
Br	82.04	82.55	81.76	
C	9.23			8.76
H	.51			.60

The barium, calcium, and potassium salts of this acid were made and analyzed. We were unable to prepare the silver salt in a form sufficiently pure for analysis. Argentic bromide began to separate even in the dark as soon as the salt was formed.

Baric tetrabrompropionate, $Ba(C_3HBr_4O_2)_2 . \frac{1}{2} H_2O$? To prepare this salt, a solution of the acid was saturated with baric carbonate, filtered, and allowed to evaporate spontaneously at the ordinary temperature.

From the concentrated solution the salt crystallized in flat prisms, which were very soluble in water. In aqueous solution the salt is permanent when exposed to the air at ordinary temperatures, but it is rapidly decomposed by heat. In the following determinations of the water of crystallization, in each case the salt was dried to a constant weight in the air and then heated until constant at 80°.

I. 1.2784 grms. of the air-dried salt lost 0.0090 grm. H_2O at 80°.
II. 1.0862 grms. of the air-dried salt lost 0.0081 grm. H_2O at 80°.
III. 1.2403 grms. of the air-dried salt lost 0.0087 grm. H_2O at 80°.

	Calculated for $Ba(C_3HBr_4O_2)_2 . \frac{1}{2} H_2O$.	Found.		
		I.	II.	III.
H_2O	.96	.7	.7	.75

1.0762 grms. of the salt dried at 80° gave 0.2747 grm. $BaSO_4$.

	Calculated for $Ba(C_3HBr_4O_2)_2$.	Found.
Ba	14.97	15.01

Calcium tetrabrompropionate, $Ca(C_3HBr_4O_2)_2 . H_2O$. When an aqueous solution of the acid was neutralized with calcic carbonate in the cold and evaporated at the ordinary temperature, the calcium salt separated from the concentrated solution in clusters of miscroscopic prisms, which were much less soluble in water than the corresponding barium salt. The air-dried salt contained one molecule of water of crystallization, which was given up at 80°.

I. 1.1413 grms. of the air-dried salt gave 0.0215 grm. H_2O at 80°.
II. 1.1087 grms. of the air-dried salt gave 0.0205 grm. H_2O at 80°.
III. 1.0948 grms. of the anhydrous salt gave on ignition with H_2SO_4 0.1895 grm. $CaSO_4$.

	Calculated for $Ca(C_3HBr_4O_2)_2 . H_2O$.	Found.	
		I.	II.
H_2O	2.15	1.88	1.85

	Calculated for $Ca(C_3HBr_4O_2)_2$.	Found.
Ca	4.89	5.09

Potassic tetrabrompropionate, $KC_8HBr_4O_2 . 2\,H_2O$. By the action of an aqueous solution of potassic carbonate on the acid a neutral solution was obtained, from which by spontaneous evaporation the potassium salt was deposited in the form of clustered needles. This salt is very soluble in water and permanent in the air at ordinary temperatures, but rapidly decomposed by heat. The air-dried salt gave up its water of crystallization over sulphuric acid.

I. 1.1571 grms. of the air-dried salt lost over H_2SO_4 0.0882 grm. H_2O.

II. 1.1304 grms. of the air-dried salt lost over H_2SO_4 0.0858 grm. H_2O.

III. 1.0354 grms. of the anhydrous salt gave on ignition with H_2SO_4 0.2165 grm. K_2SO_4.

	Calculated for $KC_3HBr_4O_2 . 2\,H_2O$.	Found.	
		I.	II.
H_2O	7.76	7.62	7.59

	Calculated for $KC_3HBr_4O_2$.	Found.
K	9.14	9.39

When heated in aqueous solution the barium salt was easily decomposed with the separation of an oil which distilled readily with steam. Since tribromethylen was the only substituted hydrocarbon that could be derived from tetrabrompropionic acid under these conditions, it was converted directly into pentabromethan. The salt was distilled with an excess of baric hydrate, and the oily distillate absorbed by bromine water. A solid residue was left after evaporation of the excess of bromine, which melted at 53° when purified by crystallization from alcohol, and on analysis gave the required percentage of bromine.

0.0918 grm. of the substance gave 0.2041 grm. AgBr.

	Calculated for C_2HBr_5.	Found.
Br	94.12	94.61

Carbonic dioxide was evolved in this decomposition, and the retort residue contained baric bromide in large quantity. It may therefore be expressed by the following equation:

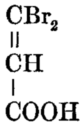
$$Ba(C_3HBr_4O_2)_2 = 2\,C_2HBr_3 + BaBr_3 + 2\,CO_2.$$

On standing with an alcoholic solution of potassic hydrate, a molecule of hydrobromic acid was eliminated from the acid with the formation of tribromacrylic acid, according to the equation:

$$C_3H_2Br_4O_2 + 2\,KOH = KC_3Br_3O_2 + KBr + H_2O.$$

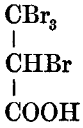
Tribromacrylic acid was recognized by its melting point, 118°, and by its crystalline form.

If the structure of β-dibromacrylic acid* is represented by the formula, —



$$\begin{array}{c} CBr_2 \\ \| \\ CH \\ | \\ COOH \end{array}$$

the bromine-addition product would have the form, —



$$\begin{array}{c} CBr_3 \\ | \\ CHBr \\ | \\ COOH \end{array}$$

The above statement concerning the behavior of β-dibromacrylic acid towards bromine, holds true with regard to chlorine. Although no action takes place at ordinary temperatures, when chlorine is passed through the melted acid the addition-product is formed without difficulty. The resulting dichlordibrompropionic acid will be submitted to further examination.

We have also tried the action of hydrobromic acid upon β-dibromacrylic acid, but as yet our results are as unsatisfactory as those of Fittig and Petri.† The product melted at about 53° and gave a percentage of bromine which showed that it contained much unaltered dibromacrylic acid. Nevertheless, by prolonged heating, we hope to obtain the tribrompropionic acid in a form sufficiently pure to enable us to study its properties.

Several attempts were made to obtain an addition-product by the action of bromine monochloride on brompropiolic acid. A substance was formed which melted quite constant at 110°–112°; but the results of analyses indicated that it was a mixture of the chlorine and bromine addition-products. In one experiment a product was obtained which melted at 102°–105°, and the percentage of bromine was very considerably increased. There is little doubt that the addition would take place, provided the bromine monochloride could be obtained in a state of purity under conditions necessary to form addition-products.

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* H. B. Hill, these Proceedings, Vol. XVII. p. 153.

† Ann. der Chem., cxcv. 73.

When brompropiolic acid is dissolved in chloroform saturated at 0° with chlorine, and allowed to stand for some time, the chlorine is absorbed with the formation of bromdichloracrylic acid.

2. ON THE DECOMPOSITION OF CHLORTRIBROMPROPIONIC ACID BY ALKALINE HYDRATES.

By C. F. Mabery.

In a previous paper by H. C. Weber and myself,[*] some experiments were mentioned in which we had attempted to determine the decomposition-products of chlortribrompropionic acid. Although our results were not entirely satisfactory, we were unable to verify them on account of the limited time at our disposal. Since the necessary material could be obtained without difficulty, it seemed worth while to define this reaction with greater precision. This work was undertaken by Mr. R. D. Wilson, who found that on prolonged heating with baric hydrate in aqueous solution chlortribrompropionic acid was completely decomposed, according to the equation, —

$$Ba(C_3HClBr_3O_2)_2 = 2\,C_2HClBr_2 + BaBr_2 + 2\,CO_2.$$

For identification the volatile product of the distillation was converted into chlortetrabromethan. It was caught in bromine water, the excess of bromine allowed to evaporate, and the oil which separated cooled to 0°. The solid thus obtained was purified by crystallization from alcohol, and its composition determined by analysis.

0.1556 grm. of the substance gave 0.3657 grm. AgBr + AgCl.

	Calculated for C_2HClBr_4.	Found.
Cl + 4 Br	93.42	93.30

Since this substance melted at 33°, it was probably identical with the chlortetrabromethan, melting point 32°–33°, obtained by Wallach and Bischof,[†] from the decomposition of β-dichloracrylic acid,

$$CCl_2 = CH - COOH.$$

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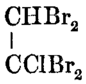
[*] These Proceedings, Vol. XVII. p. 209.

[†] Ann. der Chem., cciii. 89.

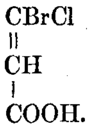
This acid gave chloracetylen, $\mathrm{CCl \equiv CH}$, which by the addition of bromine formed chlortetrabromethan, —



$$\begin{matrix}\mathrm{CHBr_2} \\ | \\ \mathrm{CClBr_2}\end{matrix}$$

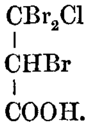
By the action of potassic hydrate in alcoholic solution upon chlortribrompropionic acid, the elements of hydrochloric acid were eliminated, with the formation in small quantity of tribromacrylic acid.

From the evident analogy between chlorbromacrylic acid, from which chlortribrompropionic was made, and β-dibromacrylic acid, the structure of chlorbromacrylic acid * is probably, —



$$\begin{matrix}\mathrm{CBrCl} \\ \| \\ \mathrm{CH} \\ | \\ \mathrm{COOH.}\end{matrix}$$

Chlortribrompropionic acid would then have the form, —



$$\begin{matrix}\mathrm{CBr_2Cl} \\ | \\ \mathrm{CHBr} \\ | \\ \mathrm{COOH.}\end{matrix}$$

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* H. B. Hill, these Proceedings, Vol. XVII. p. 153.

IV.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON THE PRODUCTS OF THE DRY DISTILLATION OF WOOD AT LOW TEMPERATURES.

By Charles F. Mabery.

Presented January 10th, 1883.

In the manufacture of acetic acid by the dry distillation of wood at low temperatures, as it is conducted by Dr. E. R. Squibb, of Brooklyn, N. Y., an oil heavier than water collects during the distillation in considerable quantities. Upon examination, Professor H. B. Hill* found that this oil contained a large percentage of furfurol, and that by the action of alkalies upon it a small quantity of pyroxanthin was formed. Further information concerning the more volatile products of the distillation therefore seemed desirable; and since different portions of the crude methyl alcohol were kindly placed at my disposal by Dr. Squibb, I undertook an examination of its constituents.

The composition of crude wood spirit has frequently been made the subject of investigation within a few years. Beside methyl alcohol and methyl acetate, which constitute the greater part of the product in the ordinary process of distillation, acetic aldehyde, acetic acid, aceton, acetal, dimethylacetal, methylethylketone, and allyl alcohol have been found in smaller quantities. Traces of the higher ketones have been detected in the less volatile portions, and in the high boiling oils small quantities of the aromatic hydrocarbons toluol, xylol, and cumol.

A study of the product under consideration shows that it has essentially the same composition. Its distinctive characteristic consists in different quantitative proportions of several constituents, probably due to the low temperature at which the first distillation was conducted.

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* These Proceedings, Vol. XVI. p. 192.

It also contains methyl formiate, which has not hitherto been recognized as a constituent of wood spirit.*

Three portions were selected for examination. The first portion (*a*) was collected at the beginning of the distillation, the second (*b*) after several hundred gallons had distilled, and the third (*c*) when the distillation of methyl alcohol was well advanced. Each portion was bright yellow in color, and from (*a*) and (*b*) a sharp penetrating odor was emitted. Since various attempts to remove the small percentage of water by desiccation were unsuccessful, the product was fractional as it was received. Anhydrous cupric sulphate absorbed only a small fraction of the water, even after standing several weeks, and fused potassic carbonate produced a decomposition, as shown by the color changing to a dark brown, with the formation of a yellow precipitate on standing. In the fractional distillation very satisfactory results were obtained, both in the separation of the different fractions and in economy of time, by the use of Hempel's† device for condensation.

The following table contains the results of the tenth fraction of each portion expressed in percentages. To insure a more complete condensation of the volatile products in (*a*), after passing through a Liebig's condenser, the distillate was cooled by a freezing mixture. Considerable gas escaped condensation at the beginning of the distillation, but it was found to consist chiefly of carbonic dioxide.

(*a*.)		(*b*.)		(*c*.)	
Temperatures.	Percentages.	Temperatures.	Percentages.	Temperatures.	Percentages.
20° - 25°	2.1				
25° - 30°	1.5				
30° - 40°	1.				
40° - 50°	1.				
50° - 52°	1.6				
52° - 54°	9.3	Below 54°	3.		
54° - 56°	62.8		74.1		
56° - 60°	7.3		3.6	Below 63°	4.7
Above 60°	6.7	60° - 70°	3.7	63° - 65°	2.5
		Above 70°	9.9	65° - 68°	57.9
				Above 68°	31.4
Loss	6.7		5.7		3.5

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* Krämer and Grodzky succeeded in isolating formic acid in small quantity from the oil obtained by adding sulphuric acid to the mother liquor of *Holzessig*, after removing the greater part of the acetic acid as sodic acetate. (Berichte deutsch. chem. Gesellsch., 1878, 1356.)

† Zeitschrift fur Anal. Chem., xx. 502.

The residue of the distillation in each case contained the greater part of the water, though in (*a*) it consisted chiefly of methyl alcohol. In (*b*) approximately one half of the residue consisted of the higher boiling oils, and in (*c*) it was composed beside water of furfurol and an oil of low specific gravity. The constituents of the various fractions will be described in detail.

Acetic Aldehyde.

In (*a*) the fraction that came over between 20° and 25° was very soluble in water, and it gave the penetrating odor characteristic of acetic aldehyde. This substance was also recognized in that portion of (*b*) which distilled below 54°, and in the fraction below 63° in (*c*). It formed a compound with acid sodic sulphite, crystallizing in flat prisms, which were very soluble in water. In order to establish its identity, an aqueous solution of the fraction 20° – 25° was boiled with an excess of silver oxide, filtered, and concentrated by evaporation. On cooling, silver acetate crystallized in characteristic forms, which, on analysis, gave the required percentage of silver.

I. 0.2222 grm. of the substance gave on ignition 0.1432 grm. Ag.
II. 0.3167 grm. of the substance gave on ignition 0.2050 grm. Ag.

	Calculated for $AgC_2H_3O_2$.	Found.	
		I.	II.
Ag	64.68	64.43	64.73

According to Krämer and Grodzky,* in the manufacture of wood spirit acetic aldehyde may usually be found in the first portions of the distillate. It is rarely present in large quantities, since, as they assert, the greater part is converted into dimethylacetal during the distillation.

Methyl Formiate.

This substance was isolated from the fractions 25° – 30° and 30° – 40°. On the addition of water an oil separated, which was purified by fractional distillation. There were thus obtained 8 grms. of a substance which distilled between 30° and 35°. It was saponified by boiling with an excess of plumbic hydrate, and the composition of the plumbic formiate determined by analysis.

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* Berichte deutsch. chem. Gesellsch., 1876, 1920.

I. 0.5214 grm. of the substance dried over H_2SO_4 gave on ignition with H_2SO_4 0.5296 grm. $PbSO_4$.

II. 0.2900 grm. of the substance gave 0.2960 grm. $PbSO_4$.

	Calculated for $Pb(CHO_2)_2$.	Found.	
		I.	II.
Pb	69.69	69.42	69.71

The presence of formic acid, and the quantity of the distillate which collected between 40° – 50°, suggested the possible formation of methylal. This fraction was therefore treated with an equal volume of water, and the oil which separated boiled with plumbic hydrate to decompose the methyl formiate. After drying with fused calcic chloride, the residue distilled above 50°. In another attempt to isolate methylal, 2,000 grms. of (*a*) were fractioned, and the distillate below 50° examined according to Dancer's method* for the separation of dimethylacetal. As in the first experiment, the residue distilled at a temperature far above the boiling point of methylal, which seemed to indicate that this substance could not have been formed in any appreciable quantity.

Methyl Acetate.

Since the fractions 50° – 52° and 52° – 54° gave reactions for aldehyde and acetone, they were evidently a mixture of these substances with methyl acetate. The greater part of the methyl acetate in (*a*) and (*b*) was collected in the fraction 54° – 56°, which boiled constant at 54°.5 – 55°.5 (Bar. 769.5 mm.). To determine approximately the percentage of methyl alcohol in this fraction, 655 grms. were saponified with potassic hydrate, and distilled. After drying with fused potassic carbonate and distilling off the methyl alcohol, there were obtained 255 grms., which came over between 66° and 67° (Bar. 769.5 mm.), or 92 per cent. of the amount required from the weight taken of methyl acetate. In repeating this saponification in a dilute solution of methyl acetate, with a potassic hydrate solution of known strength, the excess of alkali was titrated with standard sulphuric acid, and the percentage of methyl acetate calculated from the amount of potassic hydrate required to decompose it. This method gave 99.2 per cent of pure methyl acetate.

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* Ann. Chem. Pharm., cxxxii. 240.

Methyl Alcohol.

Although a small amount of methyl alcohol was contained in the higher fractions of (*a*) and (*b*), it was evidently condensed for the most part in the fraction 65° – 68° of (*c*). This fraction was slightly yellow in color, but no further attempts were made to determine its purity than an estimation of the percentage of acetone, which will presently be described.

Dimethylacetal.

The formation of dimethylacetal during the dry distillation of wood for the preparation of methyl alcohol was not observed until 1864, probably because of the small difference between its boiling point (64°) and that of methyl alcohol. After removing the methyl alcohol and acetone, Dancer* succeeded in separating a product which proved to be identical with dimethylacetal, made by heating methyl alcohol with acetic aldehyde. Krämer and Grodzky† state that it has since been recognized as a constant constituent of wood spirit. Its formation is probably due to the high temperature of the distillation, which enables the aldehyde to act upon the methyl alcohol. From the large percentage of aldehyde in the product under consideration, it would seem that this reaction had not taken place to any extent. Since an examination of the distillate below 65° in (*c*) failed to reveal the presence of dimethylacetal, a second portion of 2,000 grms. was fractioned, the lower fraction saponified and distilled over calcic oxide. The small amount of residue left after removing the methyl alcohol with calcic chloride, distilled at 57° – 58°, was readily miscible with water, and its reactions in general were characteristic of acetone. Dimethylacetal could not therefore have been formed in quantity sufficient for identification.

Acetone.

The first quantitative experiments on the influence of acetone upon the commercial value of methyl alcohol were made by Krämer and Grodzky.‡ They determined the quantity of dimethylaniline which could be obtained from a given weight of pure methyl alcohol, and also from methyl alcohol containing different amounts of acetone. Their results seemed to show that the yield was very considerably diminished if the quantity of acetone exceeded one per cent. Since crude wood spirit always contains a much higher percentage, it must be specially purified for the preparation of dimethylaniline.

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* Ann. Chem. Pharm., cxxxii. 240.

† Berichte deutsch. chem. Gesellsch., 1876, 1920.

‡ Ibid., 1880, 1005.

Various methods, dependent either upon the physical or the chemical properties of methyl alcohol, have been proposed for testing its purity. Krell[*] suggested a determination of the amount of methyl iodide which could be obtained by treating a given quantity of the alcohol with phosphorous iodide. In the hands of a skilful analyst the percentage of methyl alcohol may be accurately determined by this method; but, as Krämer remarked, it does not account for the nature of the impurities, and it is not sufficiently expeditious. To overcome these objections, Krämer[†] took advantage of the formation of iodoform from acetone. In his modification of Lieben's reaction,[‡] the formation of iodoform from ethyl alcohol and acetic acid is avoided, and acetic acid is only partially decomposed.

According to Krämer's method a mixture of 10 c.c. of a normal sodic hydrate solution, 5 c.c. of a double-normal iodine solution, and 1 c.c. of the alcohol to be tested, is shaken in a graduated cylinder with 10 c.c. of ether. 5 c.c. of the ether solution are withdrawn with a pipette, evaporated on a weighed watch-glass, and the residue weighed after drying in a warm desiccator. To obtain the weight of acetone in 1 c.c. of the alcohol, the weight of iodoform is multiplied by .28 if there are 9.5 c.c. of the ether solution.

The percentage of acetone in several fractions, as determined by this method, is given in the following table.[§] Since in each determination from 9 c.c. of the ether solution 5 c.c. were evaporated, the weight of iodoform was multiplied by .27 for the weight of acetone.

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[*] Berichte deutsch. chem. Gesellsch., 1873, 1310.

[†] Ibid., 1880, 1000.

[‡] Ann. Chem. Pharm., Suppl. VII., ccxviii. 377.

[§] In several instances the fraction was boiled with silver oxide before testing for acetone; but this seemed to have no appreciable effect on the quantity of acetone indicated by the iodoform reaction.

Fraction treated.	Specific Gravity.	Weight of Iodoform.	Weight of Acetone.	Percentage of Acetone.
54° – 56° (*a*)	0.935	0.0359	0.0097	1.04
Below 54° (*b*)	0.930	0.0648	0.0175	1.88
54° – 56° (*b*)	0.935	0.0638	0.0182	1.95
Methyl Alcohol from 54° – 56° (*b*)	0.805	0.0914	0.0247	3.07
56° – 60° (*b*)	0.830	0.0802	0.0217	2.66
65° – 68° (*c*)	0.820	0.1037	0.0280	3.41

Although the quantity of acetone in the product under consideration is sufficiently large to render further purification necessary, it is evidently much smaller than is usually observed in commercial wood spirit.

Allyl Alcohol.

The occurrence of allyl alcohol as a product of the distillation of wood was first mentioned by Aronheim,* and soon afterward Krämer and Grodzky† stated that small quantities of it may always be found in the higher fractions. In examining the aqueous part of the residue in (*c*) for this substance, after removing the water, a small amount of an oil was left, with a boiling point somewhat higher than that of allyl alcohol. It absorbed bromine readily, with the formation of a product which boiled much too low for dibromallyl alcohol, and oxidation with nitric acid gave only oxalic acid. Since from the results of Krämer and Grodzky it is usually present in wood spirit, in quantity not exceeding two tenths of one per cent, it is evidently possible that the small amount contained in 2,000 grms. might escape observation.

High Boiling Oils.

Although the composition of the higher boiling fractions was not determined with sufficiently desirable accuracy, a brief description of my attempts to isolate substances which have already been found in the less volatile portions of wood spirit may have some interest. It has already been mentioned, that beside water these fractions consisted of an oil heavier and an oil lighter than water. The heavier oil was composed chiefly of furfurol, though, as well as the water and lighter oil, it contained pyroxanthine in small quantity, which could be precipitated by the addition of sodic hydrate. 2,000 grms. of (*c*) gave 45 grms. of the lighter oil, which was pale yellow when freshly distilled, but it turned dark brown on standing. In attempting to fraction it, a constant boiling point could not be obtained between 75° and 200°. About two grms. of a substance distilled between 75° and 85°, which formed crystals with acid sodic sulphite, indicating the presence of methylethylketone; but the quantity obtained was insufficient for analysis. The penetrating odor observed in the distillate between 95° and 105° was characteristic of the allyl compounds. It was possibly due to a trace of allyl acetate, since after heating with sodic hydrate and neutralizing the solution a qualitative test for acetic acid was obtained with ferric chloride. This oil distilled for the most part between 150° and 200°. Finding, however, that a constant boiling-point could not be obtained with the supply of substance at my command, I did not consider it worth while to fraction the amount of material necessary to obtain the oil in large quantity.

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* Berichte deutsch. chem. Gesellsch., 1874, 1381.
† Ibid., 1874, 1492.

The important characters of this product, as they have appeared in the course of the preceding examination, may be summarized as follows: —

1. The high percentage of aldehyde in (*a*), of methyl acetate in (*a*) and (*b*), and of methyl alcohol in (*c*).
2. Presence of methyl formiate.
3. Absence of dimethylacetal.
4. Small percentage of acetone.
5. General purity of the product.

V.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

A SIMPLE METHOD OF CORRECTING THE WEIGHT OF A BODY FOR THE BUOYANCY OF THE ATMOSPHERE WHEN THE VOLUME IS UNKNOWN.

By Josiah Parsons Cooke.

Presented May 9th, 1883.

It is a familiar fact, that, in the usual method of accurate weighing, the buoyancy of the atmosphere produces a sensible effect, whenever the volume of the load differs materially from that of the equipoise. But, as in all the ordinary processes of chemical analysis, the analyst deals solely with relative weights, the presence of a perfectly dry atmosphere does not influence his results, unless the conditions of temperature and pressure have changed between the successive weighings; and even then the effect is insignificant in most cases. Still, when the volume of the vessel weighed is considerable, differing from that of the weights by as little even as twenty-five cubic centimeters (for example, in weighing the absorption tubes used in "organic analysis"), the error caused by variations in the density of the atmosphere may be sufficient seriously to impair the accuracy of the result.

In weighing large vessels — as in determining the density of a gas — the effect of any variation of buoyancy is eliminated by the well-known methods of calculating the results; but the formulas usually given for that purpose involve as known quantities the volume of the vessel, the volume of the weights, the density of the air under the standard conditions, as well as the temperature and pressure at the time of the several observations; and, since the calculations are somewhat complex, and the required data not always readily obtained, the formulas are seldom applied unless the volume of the load is quite large. Moreover, in these formulas the effect of each factor cannot readily be traced, and most analysts are probably not aware of the extent to which their weighings may be influenced by changes in the density of the air due to variations of temperature and pressure. In seeking to fix the weights of certain absorption tubes, (in connection with my work on the revision of the atomic weights,) I have been led to a method of correcting the weights of such tubes for variations of buoyancy; which, while it does not involve the determination of any data except the temperature and tension of the air in the balance-case, and is as simple in its application as the calibration of a flask, also gives a clear conception of the effect of each variable on the weight.

It is assumed that the air of the balance-case is dry; and with one of Becker's balances I have not been able to trace any effect on the weight of a glass vessel from variations of hygrometric condition, when two open dishes of sulphuric acid (three inches in diameter) were kept in the case, which has a volume of about thirty-seven cubic decimeters. Under such circumstances, the only causes which sensibly modify the weight of a small glass vessel (like a closed potash bulb-tube) are the variations of temperature and pressure. The relative effect of these two variables will appear from the following considerations, which suggested the method I am to describe.

If we assume thirty inches of mercury as the standard of barometric pressure, it is obvious that the variation of each tenth of an inch from this standard will determine a change of $\frac{1}{300}$ in the resultant effect of the buoyancy of the air on the load and its equipoise. Again, if we assume 27° C. as our standard of temperature, — that is, 300° on the so-called "absolute scale," — then, according to the law of Charles, the variation of each degree from this point will also cause a change of $\frac{1}{300}$ in the same resultant. In other words, counting from these standards, a variation of one degree in the Centigrade thermometer indicates the same effect on the density of the air, and therefore on its buoyancy, as the change of $\frac{1}{10}$ of an inch in the mercurial barometer. In our climate the barometer changes slowly, and its fluctuations do not ordinarily exceed one inch. On the other hand, the balances in our chemical laboratories are liable to rapid changes of temperature, which often exceed twenty degrees, the equivalent of two inches. Hence, of the two variables the temperature is by far the more important.

If we select the two standards of temperature and tension here assumed, we can easily correct for temperature by simply adding to the observed height of the barometer (in tenths of an inch) the difference between 27° C. and the temperature observed. — Of course the correction becomes negative if the temperature exceeds

27° C.—Having thus eliminated the effect of temperature, we can (after taking a few weighings under as great a variation of temperature and pressure as we can command) easily find the difference of weight which corresponds to a variation of $\frac{1}{10}$ of an inch in the barometer, and we thus obtain a constant for the vessel (or other object weighed) by means of which we can rapidly reduce the weights obtained to the standard of thirty inches' barometric pressure, having previously reduced them to the standard of 27° C. for temperature. The weights, having now been corrected for buoyancy, can be compared; and, although the standards assumed may be as unusual in their association as is one of them in its value, they are as legitimate as any others, and will be found in practice more convenient.

To apply this method of reduction we simply leave the load equipoised on the balance, shifting the rider with the varying weight, and noting the corresponding temperatures and pressures, until a sufficient difference has been observed; and a difference corresponding to 20° C., or two inches of mercury, is adequate in most cases. The process corresponds to calibrating a flask, and the constant, once obtained, can be afterwards used for the same vessel, unless the weight of its contents is materially altered. The following examples will show the application of the method.

In each case the load was a closed absorption tube of peculiarly irregular construction, but not much larger in volume than those generally used in organic analysis. We give in the accompanying tables, first, the date; secondly, the observed weight; thirdly, the temperature of the balance-case; and, fourthly, the height of the barometer at the time of weighing in tenths of an inch. These are the observed data. In the fifth column we give the reduced heights of the barometer for 27° C., and these values are obtained by simply subtracting the observed temperatures from 27°, and adding the remainders to the observed barometric heights. Below the table we print in each case the largest weight observed over the smallest weight observed, and on the same lines the corresponding reduced barometric heights. Dividing now the difference of weight in milligrammes by the difference of height in tenths of an inch, we obtain the value last given, which we have called the "constant." With this constant we can very rapidly reduce all the weights to the common standard of thirty inches, and this we do by multiplying the difference between 300 and the reduced barometric heights by this constant, and adding or subtracting the product, as the case may be, to or from the observed weights.

TABLE OF WEIGHTS.

First Series.

No.	1883.	Weight.	C.°	H.	H. reduced.	Result.
			°			
1	May 1	87.5304	17	304.0	314.0	87.5346
2	" 2	87.5303	17	304.2	314.2	87.5346
3	" 2	87.5314	19.5	303.2	310.7	87.5346
4	" 3	87.5322	20	301.0	308.0	87.5346
5	" 4	87.53205	20.5	301.9	308.4	87.5346
6	" 4	87.5320	21	302.5	308.5	87.5346
7	" 6	87.5316	18	300.8	309.8	87.5345
8	" 7	87.5320	19	300.0	308.0	87.5344
9	" 8	87.5328	19.5	298.9	306.4	87.5347
10	" 9	87.53245	22	302.2	307.2	87.5346
11	" 11	87.5333	22	299.5	304.5	87.5346
12	" 11	87.5333	19.5	296.2	303.7	87.5344
13	" 19	87.5317	21	303.5	309.5	87.5346
14	" 21	87.5345	23	296.2	300.2	87.5346
15	" 22	87.5336	22	298.0	303.0	87.5345

Greatest weight,	87.5345	Barometer,	300.2
Smallest weight,	87.5303	"	314.2
Differences,	42		14.0

Constant = 4.2 mg. ÷ 14.0 = 0.3 mg.

The balance here used is only sensitive under such a load to the tenth of a milligramme, and hence the constancy of the results obtained is very striking. There can be no question that the mean of the several weighings is accurate to the full limit of the sensibility of the instrument used. Moreover, during the course of the observations it was also evident that the slight variations observed (only $\frac{3}{10}$ of a milligramme between the extreme limits) were owing to the want of exactness in the measure of temperature of the balance-case. We used a common thermometer reading only to whole Centigrade degrees; although, as afterwards appeared, a difference of only $\frac{3}{10}$ of a degree caused a variation of $\frac{1}{10}$ of a milligramme in the weight, and a difference of a whole degree corresponded to the extreme difference between the observations. In the Second Series (made with the same tube, but differently mounted) we used a standard thermometer (Geisler's make) reading to tenths of a degree, and the results are all that could be expected with the instruments employed. The observations were made, nevertheless, under the most unfavorable conditions, during exceedingly hot weather, when the temperature was rapidly changing;

and it was evident that the insignificant differences remaining arose from the circumstance that the thermometer was not nearly so sensitive as the air in the balance-case, following the changes of temperature of the air after a considerable lapse of time. It was curious to notice the slight increase of weight, caused by the radiation of the body while weighing, followed after some time by a rise of the very sensitive thermometer employed; and this effect was obtained with a displacement of only about 75 cubic centimeters of air.

TABLE OF WEIGHTS.

Second Series.

No.	1883.	Weight.	C.°	H.	H. reduced.	Result.
1	May 29	87.3447	23.5	297.6	301.1	87.3451
2	" 30	87.3432	23.2	302.0	305.8	87.3451
3	" 30	87.3437	24.5	301.8	304.3	87.3451
4	" 31	87.3444	23.8	298.8	302.0	87.3450
5	June 1	87.3429	22.8	302.4	306.6	87.3450
6	" 1	87.3432	23.75	302.4	305.65	87.3450
7	" 2	87.3419	22.6	305.2	309.6	87.3451
8	" 3	87.3420	21.95	304.5	309.55	87.3450
9	" 3	87.3427	23.15	303.8	307.6	87.3451
10	" 4	87.3441	25.0	301.1	303.1	87.3451
11	" 5	87.3443	26.0	301.4	302.4	87.3451
12	" 5	87.3446	26.3	300.6	301.3	87.3450
13	" 6	87.34435	25.55	300.75	302.2	87.3451
14	" 7	87.3452	26.7	299.0	299.3	87.3450
15	" 8	87.3464	29.4	297.9	295.5	87.3450

Greatest weight, 87.3464 Barometer, 295.5
Smallest weight, 87.3419 " 309.6

Differences, 45 14.1

Constant = 4.5 mg. ÷ 14.1 = 0.319 mg.

NOTE. — In combining only the extreme weights, we must obviously take care that neither of them is seriously affected by any accidental errors; and a more certain value of the constant would be obtained by combining all the observations after well-known methods. This complication, however, is seldom necessary; as such errors would render the final result irregular, and lead to a rediscussion of the observations.

The limits in the accuracy of the method here described are obvious; but it will be noticed that the accuracy of the method is exactly proportional to the requirements. The greater the volume of the load, and hence the greater the effect of buoyancy, the more accurately can the "constant" be found, by which the correction required in any case can be calculated; and, as the above examples abundantly prove, the accuracy is sufficient for the purpose in view. When the volume of the load is large, it becomes necessary to measure the temperature and pressure with great precision, and to protect the balance from radiation, and from all causes of rapid change of temperature. It was a great satisfaction to the author to find that by so simple means the relative weight of glass vessels of considerable size may be determined with accuracy to the tenth of a milligramme, — an accuracy which is fully equal to that of the most refined processes of chemical analysis.

From the data given, and from the known normal density of the air, it can easily be calculated that in the first series of weighings the volume of the tube and mountings exceeded that of the weights by about 75 cubic centimeters. With this difference of volume we have a variation of $\frac{3}{10}$ of a milligramme of weight for a difference of $\frac{1}{10}$ of an inch of mercury in tension, or one degree in temperature. Hence, with a difference of volume of 100 cubic centimeters, we should have a variation of weight amounting to about four milligrammes for every difference of one inch in the barometer, or of ten degrees of the Centigrade thermometer; and these data will furnish the basis for a rude estimate of the effect in any given case. If the difference of volume amounts to 2,500 cubic centimeters, then a difference of $\frac{1}{1000}$ of an inch in the barometer, or of $\frac{1}{100}$ of a degree in the thermometer, would cause a variation of $\frac{1}{10}$ of a milligramme in the weight; so, also, a variation in the intensity of gravity amounting to only $\frac{1}{30000}$ of the whole amount would produce a similar effect, and a sensible variation would follow any marked change in the purity of the air. Hence, the balance might be used to detect exceedingly minute changes in any one of these variables, provided the others could be exactly controlled; and although with our better methods these applications of the balance may be of no practical value, yet the considerations here adduced will serve to show how sensitive the instrument is to the slightest changes in the density of the air when loaded with vessels of large volume. The best method of controlling the weight in such cases is that adopted by Regnault in his classical work on the density of the more permanent gases. This consists in balancing the vessel whose contents are to be weighed with a second vessel of equal volume, the two hanging side by side in a case lined with thick felt. The balance is set over the case, and the vessels are suspended from the pans by means of platinum wires, which swing freely through holes made in the base of the instrument.

VI.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON THE VAPOR-DENSITY OF THE CHLORIDE, THE BROMIDE, AND THE IODIDE OF ANTIMONY.

By C. P. Worcester, A. B. Harv. 1883.

Presented May 9th, 1883.

The usual form of the tube employed in Victor Meyer's method for determining vapor-densities was found unsatisfactory, in that any slight variation in the tension or the temperature of the enclosed air — such as was caused by drawing out the stopper or dropping in the substance — was apt to draw water up the delivery arm from the pneumatic trough, and so crack the hot tube. This was remedied by enlarging the delivery arm both in length and in bore. Several modifications of the tube were tried, varying in capacity from 75 to 200 cubic centimeters. The tube that was found most satisfactory was of hard glass, of the usual form (with the exception just noted), and of about 150 c.c. capacity.

The neck was closed with a perforated rubber stopper, into which was fitted a thin glass tube drawn out and closed at one end, the other end being thrust nearly through the bored stopper. The substance was weighed out in a small tube of the same size as that just described, and the open mouth of this weighing tube was thrust into the lower end of the same perforation; so that the rubber stopper both held and closed it. The stopper being tightly fitted into the neck, and the apparatus heated to a constant temperature, the upper tube was forced downwards, pushing before it the tube holding the substance, which was thus dropped into the bulb of the apparatus. As soon as the displaced air ceased to come over, the closed tip of the upper tube was broken off, thus effectually preventing the back flow from the pneumatic trough on cooling the apparatus or drawing the stopper.

Bromide of Antimony, $SbBr_3$.

The substance used being a white crystalline solid, not deliquescent and not readily oxidized, no special precautions were found necessary.

Results.

No. 1	12.71
No. 2	12.34
No. 3	12.66
Mean	12.57
Theory	12.48
Greatest difference	0.14
Mean difference	0.09

Chloride of Antimony, $SbCl_3$.

Since the chloride of antimony is very deliquescent, the substance was weighed in a closed tube, which was afterwards quickly transferred to the perforated stopper of the apparatus, arranged as above described so as effectually to protect the material from the atmosphere, till the tube was dropped into the heated bulb. Determinations were made in both air and nitrogen; but the results seemed to show that no advantage was gained by using nitrogen.

Results.

No. 1	8.06
No. 2	8.03
No. 3	7.80
Mean	7.96
Theory	7.85
Greatest difference	0.16
Mean difference	0.11

Iodide of Antimony, SbI_3.

Pure material was prepared by subliming in a stream of carbonic dioxide a quantity of an otherwise pure substance, which, by exposure to air and light, had been partly changed into the oxyiodide. Several determinations were made in the air, but the results showed that, at the temperature of volatilization, the iodide was rapidly oxidized, and the determinations were afterwards made in an atmosphere of nitrogen. Many unsuccessful attempts were made to obtain pure nitrogen by the well-known method described by Dr. Wolcott Gibbs. The method consists in simply mixing together and warming solutions of sodium nitrite, ammonium nitrate (or sulphate) in excess, and potassium dichromate in large excess, the speed of the reaction being regulated by the amount of the dichromate added. It was found that red fumes always appeared in the nitrogen evolved; and that, while no variations of proportions quite eliminated the fumes, still, when but very little bichromate was used, the resulting nitrogen was comparatively pure. It was evident, as Dr. Gibbs pointed out, that the nitric fumes were caused by chlorine present as an impurity in the materials used, and the impurity was readily traced to the dichromate; but, as the purification of potassium dichromate is troublesome and expensive, it was found more practicable to pass the impure nitrogen over red-hot copper filings recently reduced, and then through drying-tubes. The nitrogen thus purified gave satisfactory results.

Results.

No. 1	17.25
No. 2	17.90
No. 3	17.63
Mean	17.59
Theory	17.33
Greatest difference . . .	0.31
Mean difference	0.26

It will be seen that the results do not agree very closely with the theory, or with each other. While we do not presume that we have obtained as accurate results as the method will allow, a few trials carefully conducted and closely watched made it evident that very close results cannot be reasonably expected from this method. An absolutely constant temperature — indicated by the unchanging position of the water surface in the delivery tube — it is practically impossible to maintain. Furthermore, the slight resistance to be overcome by the air in rushing out of the delivery tube is often enough to retain the last bubbles, especially when there is any delay in the volatilization of the substance, giving time for the diffusion and partial condensation of the vapor. Such variable conditions seem to preclude the possibility of uniformly accurate and consistent results from Meyer's method.

VII.

NOTES ON SOME SPECIES IN THE THIRD AND ELEVENTH CENTURIES OF ELLIS'S NORTH AMERICAN FUNGI.

By W. G. Farlow.

Presented May 9th, 1883.

The third Century of Ellis's North American Fungi, issued in 1879, and the eleventh, issued in 1883, contain almost exclusively species of *Uredineæ* and *Peronosporeæ*. As a considerable number of these were collected by me, and others were examined by me at the request of Mr. Ellis, I have taken occasion in the present paper to offer certain notes with regard to the determination and distribution of some of the species, which are either new or not sufficiently well known.

In the first place, a few remarks on the nomenclature adopted are perhaps necessary. In publishing a series of *fungi exsiccati* like that of Mr. Ellis, greater latitude is naturally allowed than were one publishing a monograph of the *Uredineæ* or *Peronosporeæ*. In the latter case one would be expected to give names only to what he regards as good species, and all other names would be reduced either to synonyms, or would appear under the head of *species inquirendæ*. In issuing a series of *exsiccati*, however, one is not only at liberty to distribute species the validity of which seems to him certain, but it is frequently desirable to distribute forms which have received definite names from the earlier mycologists, although their specific value is doubtful. In the latter case, all that is incumbent on the editor is, as far as possible, to be sure that the specimen distributed really corresponds to the form which originally bore the name given. In the Centuries to which we refer, several species bear the names of Schweinitz and other earlier mycologists; and it is not to be understood that the species are really considered to be valid, but merely that, in the opinion of the editor, the specimen represents the form originally described under the name given, and that the species must be studied further.

In the case of *Peronosporeæ*, the nomenclature presents no exceptional difficulty; but the case is very different with the *Uredineæ*, which present, perhaps, greater complications than any other group of plants. Among mycologists the almost universal custom is, in case a change is made in the genus, to retain the original specific name, put the original authority in a parenthesis, and add the name of the person who first gave the correct generic name. In any work which is at all elaborate, the parenthetical name is given as well as the generic authority, and in such cases no difficulty usually arises. But in published lists or specimens distributed as exchanges, the parenthetical name is often omitted, and difficulties of interpretation arise. By retaining the parenthetical name difficulty may be avoided; but it is too much to expect that mycologists will closely adhere to the plan in practice, because it involves a good deal of trouble. In the case of Phænogams the parenthesis is not generally used, and it might be asked whether cryptogamic botanists had not also better abandon it. The usage, however, is so nearly general, that one can see very little hope of its discontinuance, at least for a good many years to come. But it must be admitted that in the case of the Thallophytes the use of the parenthesis has a value which it would not have in Phænogams. The genera of Fungi, for instance, are not so definitely fixed as in Phænogams, and the tendency seems to be to increase the number with greater and greater rapidity. A species of Fries, for instance, may during five years be dragged through no one knows how many new genera, and it is with a mildly malicious satisfaction that one sees those modern writers who adopt minute generic subdivision forced by the prevailing custom to add the (*Fr.*) as a slight tribute to the past.

If mycologists are at times too much inclined to multiply genera, they sometimes err in another direction, and in search of an old specific name pass beyond the limits of the certain, or even the probable, to what is merely vague conjecture. It is this latter tendency which has served to make the nomenclature of the *Uredineæ* at times obscure. The connection between the æcidial states and the teleutosporic states of the different species brings up the question of how this connection can be represented in the nomenclature. Shall we, in case we believe that a certain *Æcidium* is connected with a certain *Uredo* and *Puccinia*, take the oldest specific name, whether it belongs to the *Æcidium*, *Uredo*, or *Puccinia?* This is in the main the plan adopted by Winter in what I would gladly acknowledge to be the most complete systematic account which has yet appeared of the *Uredineæ* of any country. But to abandon the oldest specific name of *Puccinia*, and substitute for it an older name given to the *Æcidium* which is supposed to be connected with it, is to encounter difficulties and produce a confusion which is unnecessary. Suppose, to refer to another order of Fungi, that the conidial form of a *Pleospora* had been described as a *Cladosporium* before the ascosporic form had been described, would mycologists suppress the original name given to the ascosporic form, and retain that given to the conidia? Certainly not. The generic distinctions in the *Uredineæ* are mainly derived from the characteristics of the teleutosporic stage, and the generic names are, as far as possible, those originally given to the teleutospores. The discovery that the so-called species of *Æcidium* are states of *Puccinia*, *Uromyces*, and other genera, has not affected the generic terminology at all, and I see no reason why it should affect the specific names. As it is, the greater number of species of *Uredineæ*, excepting of course the purely æcidial forms, are recognized by the names given to the teleutosporic or *Uredo* condition, and if hereafter any particular æcidial form is found to belong to them, I see no reason why the specific name should be changed because the *Æcidium* was described before the other stages. As soon as an *Æcidium* is found to be connected with another form, its name should disappear, and it should simply be called the æcidial or hymeniferous condition of the species of *Puccinia*, or other genus to which it belongs, unless, of course, for purposes of what may be called mechanical convenience, one retains the æcidial name unchanged in exchanges or lists.

For practical reasons, if for no other, the custom of substituting an æcidial specific name for a name given to a *Uredo* or teleutosporic form should by all means be avoided. Of all the *Uredineæ* described by older writers, probably none are more difficult to determine satisfactorily at the present day than the species of *Æcidium* so called. Original specimens of that genus are as a rule not so well preserved as those of other genera of the order, and if one usually gets little satisfaction from examination of what is left of the original types, he is scarcely any better off on reading the older descriptions. It was not unfrequently the habit of older mycologists to describe as varieties of one *Æcidium* forms found on the most diverse plants, and most certainly it is going too far to substitute for the name of a *Puccinia*, let us say, which has passed current for many years, the name given by an old authority like Persoon or Link to what he considered a variety of an ill-defined *Æcidium*. It cannot be said that any want of respect to the older writers is shown by abandoning their æcidial names in such cases. In this connection we might mention one of our own species. There is a *Puccinia* which grows on *Claytonia,* which was described by Peck and Clinton in 1873. It is now well known that this *Puccinia* is often accompanied by what was described by Schweinitz in 1831 as *Cæoma* (*Æcidium*) *Claytoniatum.* It is inferred that one form is a stage of the other, and, supposing that this inference is correct, shall we say, instead of *Puccinia Mariæ-Wilsoni* Clinton, *Puccinia Claytoniata* (Schw.) Farlow? I am distinctly of the opinion that such a change should not be allowed. The case mentioned is one of the strongest, and other instances are less favorable still.

One more point needs to be considered. If one is not justified in going back to æcidial specific names, is he justified in going back to old Uredo names? It seems to me that one is justified in this, and that the objections urged in the case previously mentioned do not apply to any great extent here. As a matter of fact, the types of the earlier described Uredo forms are much better preserved than *Æcidia,* and examinations of older herbaria frequently enable one to determine with accuracy what form was meant by an older author. Furthermore, the Uredo and teleutosporic forms frequently are found together in the same sorus, or in close proximity, and examinations of authentic specimens often show the relation of an old described Uredo to a more recently described teleutosporic form. The most important consideration, however, is the following. Many of the forms now recognized as teleutosporic have one-celled spores, and were originally described as forms of *Uredo,* and in such cases one must go back to the original specific names. We may mention several of our species of *Uromyces* originally described by Schweinitz as species of *Uredo.* Whenever an examination of Schweinitz's specimens of *Uredo* enables us to recognize a species of *Uromyces* or *Puccinia,* we are warranted, I think, in substituting a Schweinitzian specific name for a more recent one, and placing his name as authority in a parenthesis. A number of Schweinitz's species of *Uredo* are so generally known to belong to *Uromyces, Coleosporium,* and other genera, that the use of the parenthesis is often omitted, until some mycologist desirous of adding his name to as many new species as possible gains a cheap reputation by appearing suddenly in print with his name attached as authority to an old and well-known Schweinitzian species.

If I have advocated retaining the older Uredo name in cases where we know with certainty what was meant by the earlier mycologists, I have by no means intended encouraging the use of names about which there is doubt, either from the absence of typical specimens, or confusion of several species by older writers. Rather than favor that method — if one may say so — of forcing priority, I should prefer to give up the substitution of all old Uredo names, except, possibly, in the case of species now referred to *Uromyces*.

To make a long story short, I am of the opinion that in naming *Uredineæ* we should go back to the oldest specific name given to the teleutosporic form or to the Uredo form, provided sufficiently good data exist in older writings or herbaria to enable us to ascertain with certainty whether the Uredo named actually was associated with the teleutosporic form; and this can in many cases be settled by reference to older herbaria. The connection between teleutosporic and æcidial forms certainly was not suspected until recent years; and, as it seldom happens that in old herbaria the two forms are found intimately associated, and, furthermore, as the whole group of *Æcidia* are rather vaguely characterized by older writers and poorly preserved in herbaria, it seems best to abandon the attempt to go back to the original æcidial name. Where the practice might succeed in one case, it would produce uncertainty in many more; and while, on the one hand, there is danger that sufficient attention may not be paid to priority, there is, on the other, still greater danger that, by attempting to do too much, the nomenclature of *Uredineæ* may become hopelessly entangled.

In the North American Fungi a considerable number of forms of *Æcidium* have been issued, sometimes with a reference on the label to the teleutosporic form to which they have been referred, but in most cases without such reference. In this country it seems to me that in general a conservative policy had best be adopted in regard to associating our *Æcidia* with teleutosporic forms. Information is always to be desired; hasty assumption, however, is an entirely different matter. In Europe so many excellent observers have experimented on the connection between different forms, that in regard to European *Uredineæ* one can venture to make a statement of the subject in systematic works. In this country almost nothing has been done in an experimental way, and, if one will only bear in mind the peculiar relations which *Æcidia* and *Uromyces* on *Euphorbiæ* are considered to bear to one another in Europe, he will recognize that we in this country cannot assume that, because an *Æcidium* and a *Puccinia* or a *Uromyces* occur on the same host, even when in close proximity, they are really stages of one species. All one can say is that such is probably the case. In papers describing our *Uredineæ* one should of course state, as far as he knows, what *Æcidia* are found with teleutosporic forms; but to go farther than this in our endemic species, and in several of the species which also occur in Europe, is in my opinion undesirable. To group together hastily different forms is a very easy matter; but it is more to one's credit to be willing to wait until future study shall have shown what forms really are connected.

Synchytrium fulgens Schrt. var. *decipiens* Farlow, no. 201, and *S. Anemones* Wor., no. 203, are now known to be common in the Western as well as the Eastern States, but apparently *S. papillatum* Farlow is not known beyond the region where it was first collected by Dr. Anderson.

No. 207, *Peronospora obducens* Schrt., has also been found in Iowa by Professor C. E. Bessey, and in Illinois by Mr. A. B. Seymour. I at first supposed that this fungus appeared only in the spring on the cotyledons and occasionally the youngest leaves of *Impatiens*, but it was found by Professor William Trelease to be common on the mature leaves of *Impatiens* collected at Wood's Holl in August, 1880. The cotyledons are generally thickly covered by the conidia, but on the leaves the spots are generally small and scattered. I have myself never found ripe oöspores, and only rarely the young oöspores, of this species, but they were found fully developed by Mr. Seymour in specimens on *Impatiens* collected in Illinois. They occur in large numbers in the petioles and young stems from just beneath the epidermis to near the vascular bundles. The oögonia measure from 38–45μ in diameter, and the oöspores themselves are from 26–31μ in diameter, with an endospore about 3μ thick. The outer wall of the oöspores is nearly smooth, but usually has a few ill-defined folds or ridges, not, however, to be compared with the markings on the oöspores of some other species.

No. 208, *Peronospora viticola* (B. & C.) De Bary. In the Bussey Bulletin, Vol. I. p. 422, March, 1876, I made the statement that practically no harm was done to the grape crop in our Northern States by this fungus, but added, "Should the fungus be introduced into Central Europe, the case might be different." Since that date, as every one knows, this parasite has been introduced into Europe, and an enormous amount has been written relating to its spread on the Continent and the harm that it has caused. On the latter point authorities differ, some going so far as to assert that it does as much harm as the *Phylloxera,* and others that it does perceptible harm only in exceptionally moist seasons. The majority of writers, however, believe that considerable damage is done by the fungus, and the statement made in the Bussey Bulletin is not credited. While admitting the damage done in other regions, I have seen no reason for changing my opinion with regard to the harmlessness, practically speaking, of the *Peronospora* in New England. I never meant to deny that, theoretically speaking, the existence and growth of a parasite like *P. viticola* would weaken the vines in which it was growing; but the fact is that I have repeatedly seen vines attacked by the *Peronospora* produce good crops of grapes year after year, and, whatever we might expect in theory, in practice no perceptible harm is done to the open-air grape culture in New England. In that region, as was stated in the Bulletin, the great danger to be dreaded is the occurrence of frosts before the grapes have ripened, and the *Peronospora*, in so far as it causes the leaves to curl up, thus exposing the grapes to the full force of the September sun, benefits rather than injures the grape crop. The position of New England and the northern parts of the United States with regard to grape culture is quite exceptional, and there is evident reason why what is true of the *Peronospora* here should not be true in other parts of the world.

Nos. 209 and 210. *Peronospora Halstedii*, Farlow. This species was referred to in the Bussey Bulletin, Vol. II. p. 235, January, 1878, where mention was made of a *Peronospora* found by Mr. B. D. Halsted on *Eupatorium purpureum*, near the Bussey Institution, in May, 1876. Since then the fungus has been collected in numerous other localities and on several different hosts, and it may now be regarded as one of our most widely spread and characteristically American species. It was found by Professor Bessey, in August, 1878, on *Eupatorium purpureum*, *Bidens frondosa*, and *Rudbeckia laciniata*, and since then it has been observed by Professor Arthur on *Helianthus doronicoides* in Iowa; on *Helianthus strumosus* and *Silphium terebinthinaceum* in Wisconsin, by Professor Trelease; on *Helianthus tuberosus* in West Chester, Pa., by Mr. J. B. Ellis; and I have myself also found it on *Ambrosia artemisiæfolia* in several different localities. In short, we may expect to find it on almost any Composite, although it apparently affects principally the *Tubulifloræ*, while with us *P. gangliformis* affects rather the *Ligulifloræ*. The ripe oöspores of *P. Halstedii* are not common, as far as my experience goes; but I have seen them in good condition on the leaves of *Helianthus doronicoides*, collected at Charles City, Iowa, by Professor Arthur. The conidia vary in their development according to the host, forming large and conspicuous patches on *Rudbeckia*, *Silphium*, and *Helianthus tuberosus*, but rather inconspicuous spots on *Ambrosia*. The conidial spores vary very much in size, and their shape, as in all *Peronosporæ*, depends much on their age; when young oval, when about to germinate, elliptical and slightly papillate. In germination they produce zoöspores like *P. viticola.* The germination I have observed in the form growing on *Ambrosia* at Wood's Holl, and it differs in no essential respect from what takes place in all our zoöspore-producing species, to which reference will be made hereafter. The nearest ally of the present species is *P. viticola*, from which *P. Halstedii* differs but little in morphological characters; but in *P. viticola* the ultimate branches are distinctly more dense, so that the tips almost appear denticulate at times, while in *P. Halstedii* the ultimate branches are more or less subulate and divaricate. In *P. Halstedii* the haustoria are numerous in the leaves, nearly globular, and much more easily seen than in *P. viticola.* The oöspores of the two species resemble one another, but those of *P. Halstedii* appear to be on an average larger, and the epispore more distinctly in irregular folds. As might be expected, a species appearing on so many hosts presents modifications on the different hosts. The most marked deviation from the type is seen in the form on *Helianthus tuberosus* from Mr. Ellis. In the type the conidial stalks consist of a main axis, from the upper part of which are given off lateral branches nearly at right angles; the branches then give off a second and third series of branchlets, which usually end in a prong-like projection, near the base of which are from two to four similar prongs in a divaricating tuft. The general outline of the conidial ramifications is pyramidal, while in *P. viticola* it is more nearly linear. In the form on species of *Helianthus* the lower branches are often much longer and more frequently divided than in those on *Ambrosia* and *Bidens*, and the branching becomes almost thyrsoidal. In rare cases, the usually erect prong becomes recurved, and the tip of the branchlet swells so that there is an approach to *P. gangliformis*, from which, however, it can easily be distinguished by the different ramification. Were it not for the large series of connecting forms, one might be inclined to separate the specimens of Mr. Ellis as a distinct species. The following may serve as a description: —

P. HALSTEDII, Farlow. Mycelium furnished with numerous oval haustoria. Oögonia 30–40μ in diameter. Oöspores spherical, yellowish, 23–30μ in diameter, epispore with ill-defined folds, endospore about 3μ thick. Conidial stalks fasciculate, narrowly pyramidal in outline, with a percurrent axis, 11–15μ in diameter, 300–750μ long, two – four times pinnate, branches given off nearly at right angles, ultimate divisions approximate in clusters of three or four divaricating tips. Conidial spores colorless, oval or elliptical, with a slight papilla, 19–30μ long by 15–26μ broad, germinating by zoöspores.

HAB. Leaves of *Eupatorium purpureum* L., *Ambrosia artemisiæfolia* L., *Bidens frondosa* L., *Rudbeckia laciniata* L., *Silphium terebinthinaceum* L., *Helianthus strumosus* L., *H. doronicoides* Lam., and *H. tuberosus* L.

In the Bussey Bulletin for 1876 less than a dozen *Peronosporeæ* were enumerated as known in the United States, but since that date the number has been very much increased. Reference will be made later on to the additions to our flora, but in this connection I would call attention to the large proportion of species whose conidial spores produce zoöspores. I have studied the germination in *P. viticola*, *P. Halstedii*, *P. obducens*, and *P. Geranii*, no. 218, North American Fungi, and find that the spores all produce zoöspores in germinating, although I have experienced difficulty in making those of the last named species germinate, having tried for several years in vain. Besides the species just enumerated, *Peronospora* (*Basidiophora*) *entospora* Cornu and Roze, which according to Cornu also germinates by zoöspores, is now known in at least three localities in this country.* Counting also the potato-rot, we have six species which produce zoöspores. Of these *P. viticola* and *P. Halstedii* are distinctly, and *P. entospora* probably, of American origin. *P. obducens* was discovered almost simultaneously in Baden and in Massachusetts, and as it is about equally common on both continents on indigenous species, we have no guide to its original home. *P. Geranii*, it seems to me, can on morphological grounds with difficulty be distinguished from *P. nivea* on *Umbelliferæ* in Europe, and I previously regarded it as a variety of that species. Certainly, if there is a difference, I was not able to express it in words. It is, however, distinct from any European form on *Geranium*, and as the majority of Continental botanists will not admit that the same *Peronospora* can grow on species of orders as remote as *Geraniaceæ* and *Umbelliferæ*, in their sense, at least, *P. Geranii* must be considered peculiar to America. I once tried without success to cultivate it on an Umbellifer, but that hardly shows anything, as under all circumstances — and I have tried many times — the conidia of this species are with difficulty made to germinate at all. One naturally asks why it is that such a large proportion of our species produce zoöspores instead of direct germinal tubes. From their close resemblance one might suppose that *P. viticola*, *P. Halstedii*, and, to stretch the matter somewhat, possibly *P. Geranii*, were derived from some common American ancestor which produced zoöspores. If, in the various surviving species, we find this common peculiarity of germination preserved, we ought certainly to suppose that this form of germination is especially adapted to the climatic and hygrometric conditions of our country. Strange to say, the contrary appears to be more probable. Our climate is a continental one, subject to extremes of heat and moisture, and one would suppose that a species with spores so contrived that they could push forth germinating tubes would be more likely to survive in comparatively dry seasons than one arranged to give out a number of zoöspores; for it is the result of my experience that the tube-producing spores retain their vitality for several days, whereas those which produce zoöspores lose their power of germinating in a comparatively few hours after maturing. It may be said, on the other hand, that the chances of survival are greatest if the spores usually produce zoöspores, but in exceptional cases produce germinal tubes. *P. infestans*, which usually produces zoöspores, is known occasionally to produce tubes, but of the hundreds, or even thousands, of germinating spores of *P. viticola* and *P. Halstedii* I have seen, I never met with one producing anything but zoöspores.

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* The species was originally found on *Erigeron Canadense* in France, and has since been found in Germany. I first received American specimens from Professor T. J. Burrill, of Champaign, Ill., by whom it was found on *Erigeron* in May, 1878. The species afterwards was described in the Thirty-first Report of the New York State Museum as *Peronospora simplex* Peck, on *Aster Novæ-Angliæ*, from New York, and it has since been found by Trelease in Wisconsin, on *Aster Novæ-Angliæ*. Although I have often searched, I have never found it near Cambridge, but instead *Cercospora cana* Sacc., which to the naked eye resembles it. Probably the species is a native of America, and was introduced into Europe with *Erigeron*, following the example of *P. viticola*. *P. Halstedii*, as far as I know, is not yet known in Europe, but it may be expected to appear there at any time, and may do a real injury to the crops of *Helianthus tuberosus*, which is largely cultivated in several parts of Europe.

No. 228. *Æcidium Convallariæ* Schm. var. *Lilii*. This was found in June growing on cultivated *Lilium candidum*, but was not followed by any uredo or teleutospores. It certainly is not *Æcidium Liliacearum* Ung., which is associated with *Uromyces Liliacearum* Ung., nor the æcidium of *Puccinia Liliacearum* Duby, but rather a large form of *Æc. Convallariæ* Schm., of which no. 229 on *Polygonatum* is the more common form.

No. 230. This is the common form of *Æc. myricatum* Schw. The small form distributed with Cent. XI. is only known to me from Mr. Ellis's specimen.

No. 225. It is possible that there was a mixture of two species under this number, as in my copy I notice one leaf with *Æc. punctatum* P.

No. 1003. It may be doubted whether either the form on *Ranunculus abortivus* or that on *Anemone nemorosa* is the same as the *Æc. Ranunculacearum* DC., or the form associated with *Uromyces Dactylidis.* The fungus on *R. abortivus* is the *Æc. Ranunculi* of Schweinitz's Syn. Car. no. 440, afterwards referred to *Æc. Ranunculaceatum* Lk. in the Syn. Am. Bor. The form on *Anemone* has the æcidia in spots, as in *Æc. Ranunculacearum* DC., but the small size of the æcidia, as well as other peculiarities, leads one to ask whether it is not distinct from all the forms on *Ranunculus.*

No. 1004. *Æcidium Thalictri* Grev. Mr. Ellis informs me that by accident the wrong specimens were distributed with this number, and that the true species will be distributed later.

No. 1007. I can see no good ground for separating this from *Æcidium Violæ* Schm. Authentic European specimens of that species have spores as large as this. *Æc. Petersii* B. & C., which also occurs on violets, has slenderer and longer peridia.

No. 1018. The three forms on *Rudbeckia*, *Xanthium*, and *Solidago* may, for want of any satisfactory information as to their relationship, be called *Æc. Compositarum;* but it is perhaps going too far to give Martius as the authority. The form on *Xanthium* is in Massachusetts frequently followed by the *Puccinia Xanthii* of Schweinitz, distributed as no. 264.

Nos. 1021–1026. In another paper I shall refer to the distribution of the *Peridermia* of the White Mountain region, and the names and authorities here given are taken from Thümen's *Blasenrost Pilze der Coniferen* without criticism. The *P. orientale*, no. 1026, apparently common in the Southern States, is rosy flesh-colored when fresh, and is probably what is figured by Bosc in Gesell. Naturf. Freunde, Vol. V. Pl. 6, f. 13, as *Tubercularia carnea.*

No. 1084. The spermogonia of this species usually appear on the leaves, while the æcidia are more common on the fruit and smaller twigs.

No. 1086. The typical form of *Roestelia penicillata* Fr. is well shown in the specimens on the fruit of *Amelanchier.*

No. 1087. Apparently *R. Botryapites* Schw. occurs in its most luxuriant form on *Amelanchier*, growing near the seashore, as shown in the specimen from Magnolia, Mass.

No. 1089. This is the typical *R. cornuta* Tul., and is abundant at Eastport, Me., where it is associated with *Juniperus communis*, which on the coast of Maine is infested by *Gymnosporangium clavariæforme* DC., no. 273. It is supposed, however, in Europe, that *R. cornuta* is connected with *Gym. conicum* DC., which does not occur with us in the region where the typical *R. cornuta* abounds.

Nos. 277 and 278. The *Æcidium nitens* of the Syn. Fung. Car. Sup., changed by Schweinitz to *Cæoma luminatum* in the Syn. Fung. Am. Bor., is probably the most striking and brilliant member of the *Uredineæ* in the Eastern United States, where it is extremely common on several wild species of *Rubus*, being familiar to every child. In spite of its frequency there is as yet no clue to its connection with any other form. The spermogonia are very abundant, and cover both surfaces of the leaves, and the petioles, looking to the naked eye like minute greenish-yellow glands. They cause a peculiar deformity of the younger shoots, which become longer and slenderer than usual, and paler in color, and the leaves remain small and unexpanded. The spermogonia, instead of being wholly or partly immersed in the leaf, as in most species, are entirely above the surface of the epidermis, which rises so as to form a cup, often contracted at the base, leaving the whole body of spermatiferous threads projecting in somewhat club-shaped glutinous masses, either quite naked or covered for a time by the cuticle only. The spermatia are nearly spherical. The spores are arranged in rows like the uredo of *Coleosporium*, and when fully ripe are somewhat hexagonal in outline, the wall being thinner at the angles. In germination they give off long hyphæ from the angles, and not promycelia proper. The present species resembles in many respects the forms placed by Tulasne, in his *Second Mémoire sur les Urédinées et les Ustilaginées*, in the genus *Cæoma*, using the name in a more restricted sense than Link and Schweinitz, and on that account the generic name *Cæoma* was given in the North American Fungi. On grounds of priority the specific name *nitens* should be kept; but, of course, in our ignorance of the connection of this form with others, no generic name can be given which it may not be required to change in a short time. One might suppose that we had here the æcidium of some *Phragmidium*, as the æcidia of that genus as understood by Winter resemble our plant. I have never been able to trace any connection, however, between our rust occurring early in the season and any subsequently appearing *Phragmidium* or *Coleosporium*, and the probabilities are that the species is heterœcious.

Nos. 247 and 248. *Pileolaria brevipes* B. & Rav. Mycologists have been in doubt as to the teleutosporic form of this species. The more common form is the uredo, no. 247, in which the spores are depressed-globose and covered with roughnesses, and it is to this form that the name *Pileolaria brevipes* was first given. The teleutospores, which are more frequent toward the end of the season, are short-stalked, ovate, with a distinct hyaline papilla at the apex, and are marked with spiral lines or dots arranged in spirals. This latter stage is the *Uredo Toxicodendri* of Ravenel's Fung. Car. III., no. 797, described by Berkeley in Grevillea, Vol. III. p. 56, under the name of *Uromyces Toxicodendri*. It seems to me that Léveillé and Tulasne were right in considering that *Pileolaria* is not distinct from *Uromyces*. The same view is adopted by Winter, by whom, however, in the European species, *P. Terebinthi* Cast., the depressed globose spores are considered to be the teleutospores, and not the uredo stage. The Californian form on *R. diversiloba* seems to me the same as that found on *R. Toxicodendron* in the East. A second species, *P. effusa*, has been described by Peck on species of *Rhus* from Arizona. Inasmuch as the *P. brevipes* and *U. Toxicodendri* were both distributed first in Ravenel's Fung. Car. Sup. in 1855, it seems to me that, assuming the fungus to be a *Uromyces*, the name to be adopted by preference is *U. Toxicodendri* Berk. & Rav.

Nos. 239 and 240. The species of *Uromyces* growing on *Gramineæ* are especially perplexing in this country. The two numbers here distributed are forms mentioned in the Bussey Bulletin, Vol. II. p. 243, that on *Spartina* being considered to be probably a variety of *U. Junci*. Since then I have been able to examine more fully the various forms of *U. Junci*, and must now consider that the form on *Spartina* is distinct. The teleutospores resemble strongly those of *U. Junci* (Schw.) Tul., but the uredo spores are larger and differently colored, so that the species is easily recognized when they are present.

UROMYCES SPARTINÆ Farlow. Sori long and narrow, soon naked. Uredo spores orange-colored, long-stalked, globose or somewhat elliptical, 25–34μ in diam., average 30μ, echinulate. Teleutospores smooth, dark brown, long-stalked, 26–32μ by 15–19μ, ovate, narrowed at the base, apex acute or rarely truncate, with a thick wall.

On *Spartina stricta*, submerged at high tide. Wood's Holl, Mass. July and later.

As yet I have only seen this species at Wood's Holl, but it is to be expected anywhere on the New England coast. The only *Æcidia* seen growing near this species were those on *Xanthium* and *Statice*, which can hardly be supposed to have any connection with the present *Uromyces*, as they are accompanied by *Puccinia Xanthii* and *Uromyces Limonii* respectively. In the description I have said nothing about paraphyses, although the teleutospores are mixed with hyaline threads which may be paraphyses, although they are possibly merely the long stalks which have already borne uredo spores.

The *Uromyces* on *Brizopyrum* occurs from New Jersey to Gloucester, Mass., and is apparently common. It has been considered a form of *U. Dactylidis* Otth., a species with regard to the limits of which I can form no very clear idea, as the descriptions given by European writers do not entirely accord with authentic specimens. In its typical condition *U. Dactylidis* has sori which are long covered by the epidermis, and there are numerous capitate paraphyses. *Capitularia Graminis* Niessl in Rabh. Fung. Eur. no. 1191 is regarded as merely a form of *U. Dactylidis*, but in this form the sori are naked and prominent, and the paraphyses not plain. Our form on *Brizopyrum* approaches closely to the 1191 of Fung. Europ., and it is perhaps not very plain why, if *U. Dactylidis* includes the specimen in Rabenhorst, it should not be extended so as also to include our form. Such, however, is not the opinion of European botanists who have examined American specimens, and on that account the fungus was distributed as *U. Peckianus* Farlow, as it was first detected by Peck, by whom it was considered to be identical with *U. Graminis* Cooke. As it is, the distinction between *U. Peckianus* and *U. Dactylidis* lies in the fact that in the former the sori are naked, the teleutospores are longer-stalked, have a thicker wall, which is of nearly uniform thickness throughout, not being denser at the apex, which is always obtuse, and not pointed. The paraphyses are filiform and mixed with the teleutospores, and not arranged in a ring around the sorus.

U. PECKIANUS Farlow. Sori oblong or linear, naked and becoming convex. Uredo spores short-stalked, yellowish brown, echinulate, globose, 18–21μ in diameter. Teleutospores mixed with filiform paraphyses, dark brown, long-stalked, oval or elliptic, smooth, 22–34μ by 19–23μ, narrowed at base, apex obtuse, cell wall scarcely if at all thickened at apex.

On *Brizopyrum spicatum*. New Jersey to Gloucester, Mass. Autumn.

Nos. 1067 and 1068. *Uromyces Martinii* Farlow. With regard to the æcidium, no. 1098, I at first supposed that it immediately preceded or accompanied the *Uromyces;* but that not being the case, it is hasty to assume a connection between the two, and, without wishing to give a name, it is distributed for further study by mycologists. The name *U. Martinii* is given to 1067 because, although there is a *Uromyces Melantheræ* Cooke on *Melanthera Brownii* from Natal described in Grevillea, June, 1882, the description there given of the teleutospores does not accord with the present species. It is there stated: "III. Soris pallidis, compactis, hemisphericis. Teleutosporis lanceolatis, pallidis, lævibus (.05 × .02 mm.). Episporia supra incrassato." I add a description of the Florida fungus.

UROMYCES MARTINII Farlow. Sori round, naked, scattered irregularly over both sides of the leaves. Uredo spores pale brown, oval, and occasionally triangular in outline, echinulate, 18–22μ in diam., average 20μ. Teleutospores dark brown, short-stalked, globose or broadly elliptic, 26–35μ by 22–26μ, cell wall thick, smooth or slightly roughened, apex with a prominent hyaline, broadly conical papilla.

On *Melanthera hastata*. Florida. Dr. Martin.

The species, it will be seen, is characterized by its broad, globose, thick-walled teleutospores, with very marked hyaline papilla at the apex. The uredo spores not unfrequently are more or less triangular in outline, but whether this is the result of drying I cannot say. At any rate, potash fails to restore the original form, if it were oval. A comparison with the description of *U. Melantheræ* shows that the description of the uredo spores corresponds more closely to the teleutospores of our plant than to the uredo spores, and were it not that the expression "teleutosporis lanceolatis" occurs, one would say that our fungus and that from Natal were the same, and that there was an inversion in the description of the uredo and teleutospores.

No. 1072. *Uromyces Liliacearum* Unger. In Rabenhorst's *Kryptogamen Flora* this species is placed by Winter in the subgenus *Uromycopsis*, in which æcidia and teleutospores are known, but the uredo is wanting. I found the uredo and teleutospores of the species growing together at Shelburne, N. H. The uredo sori are small and long covered by the epidermis, and the spores are oval, bright yellow, and measure 23–26μ in diameter, the surface being slightly echinulate. In this connection it may be remarked that, in his Twenty-seventh Report, Peck mentions the occurrence of a uredo on *Lilium Canadense*, which he refers to *U. Smilacis* Schw. The present species is also found in Massachusetts, where the æcidium accompanies or immediately precedes the *Uromyces*.

No. 1073. *Calyptospora Gœppertiana* Kühn. Although known for some time in the Western States on *Vaccinium ovalifolium*, the species has not frequently been found in the East. I have already called attention to its occurrence on *Vaccinium corymbosum* near Boston, where it is rare, but it is common in the White Mountain region on *V. Vitis-Idæa*, and also less frequently on *V. Canadense* and *V. Pennsylvanica.* It has recently been found to be common on *V. corymbosum* at Hanover, N. H., on the Connecticut River, where it has been collected by Professor Jessup.

No. 253. Through an error in my manuscript, the label was originally printed *Puccinia microspora* B. & C., instead of *P. microsperma* B. & C., which was the name given by Berkeley in Grevillea, December, 1874. The name *P. Lobeliæ* Gerard, in Bull. Buffalo Soc. Nat. Sci., June, 1873, has, however, priority.

No. 257. The name which this *Puccinia*, common on *Podophyllum*, should bear, is *P. Podophylli* Schw. In the Syn. Fung. Car. Sup., 1822, Schweinitz described an *Æcidium Podophylli* and a *Puccinia Podophylli.* In 1825, in the Species Plantarum, Vol. VI. Part 2, Link described a *Puccinia aculeata* and a *P. Podophylli.* To the former he refers Schweinitz's *P. Podophylli*, and to the latter the *Æcidium Podophylli* Schw. In 1831, in the Syn. Fung. Am. Bor., Schweinitz changed the name of *P. Podophylli* to *P. aculeata*, giving his own name, and not that of Link, as the authority. Original specimens of Schweinitz's *Æcidium Podophylli* show that it is really an *Æcidium*, and not a *Puccinia*, and the reference in Link is incorrect. There is no reason why the original name of Schweinitz, *P. Podophylli*, should not be retained, instead of the later name *P. aculeata.*

No. 260. *Puccinia Epilobii* DC. var. *Proserpinacæ* Farlow. I have found this fungus twice, once at Wood's Holl in August, and once in Cambridge in October. The teleutospores germinate at once in the sorus, even those found as early as August, and the species on that account would be referred to the subgenus *Leptopuccinia*, to which the pulvinate sori and closely packed spores also point. But the presence of a uredo is not supposed to occur in *Leptopuccinia*, and in the present species there is a well-marked uredo. Evidently, the reference of the species to *P. Epilobii* as a variety is incorrect, as a careful examination of the teleutospores shows that they are larger and of a different shape from those of *P. Epilobii.* It should be compared with no. 1060, *P. Œnotheræ* Vize, from California, to which it is very closely related, and with which it may be identical, although I should not wish to speak with certainty on the latter point without examining a larger set of specimens than I have seen. I give a description of the Massachusetts plant for comparison with the Californian plant, without meaning to imply that I consider the two clearly distinct.

PUCCINIA PROSERPINACÆ (forma *P. Epilobii* Vize ?). Sori round, scattered, soon becoming naked. Uredo spores yellowish brown, oval, echinulate, 20–26.5μ in diameter, average 22–23μ. Teleutospores brown, densely packed and germinating in the sorus, short-stalked, clavate, contracted somewhat at the septum, apex rather acute, with thickened cell wall, 38–53μ × 17–21μ.

Differs from *P. Epilobii* DC. in its distinctly longer, clavate teleutospores.

No. 1029. This common *Puccinia* on *Panicum capillare* and apparently other species of grasses, both in the Eastern and Western States, is certainly the *P. emaculata* of Schweinitz, Syn. Fung. Am. Bor., no. 2912, of which I have examined an original specimen. It has been called *P. Graminis* var. *brevicarpa* by Peck in his Twenty-fifth Report, where, however, it is stated that it is possibly *P. emaculata.* It seems to me to differ from *P. Graminis* both in the uredo and teleutospores, and I add a description to furnish details not given by Schweinitz. Whether it cannot be referred to some older name than that of Schweinitz is a question I am unable to answer. It is found in some herbaria under the name of *P. Caricis,* a species to which it has, superficially, a greater resemblance than to *P. Graminis.*

PUCCINIA EMACULATA Schw. Sori at first small and oblong, soon becoming confluent and linear, naked, uredo spores brownish, nearly globose, echinulate, 18–21μ in diameter. Teleutospores dark brown, on stout stalks, mixed with subclavate paraphyses, oval or elliptical, obtuse or somewhat contracted at the base, apex obtuse and thickened.

In this connection it may be remarked that *Puccinia Ellisiana* Thm., in Torr. Bull., Vol. VI. p. 215, and Myc. Univ., no. 1336, does not differ from *P. Andropogi* Schw. Syn. Fung. Am. Bor., no. 2911, published in 1831. I have examined an original Schweinitzian specimen and compared it with Myc. Univ., no. 1336.

No. 1031. *Puccinia Veratri* Duby. Although the identity of this species offers no special difficulty, writers differ with regard to the authority. Niessl, who mentioned the species in 1859 in the Verh. Zool. Bot. Ges., is usually quoted as the author, but Duby in Bot. Gall., Vol. II. p. 890, published in 1830, described a *P. Veratri,* under which he quoted *Uredo Veratri* DC. I have French specimens bearing the date 1843, labelled *P. Veratri* Duby, which corresponds in all respects to the No. 1031 of Ellis's Fungi, and, as I have no reason whatever to doubt the authenticity of the specimens, I have adopted the name of Duby. *Uredo Veratri* DC. is considered by writers to be a *Uromyces,* and it may be that it was erroneously connected by Duby with his *P. Veratri;* but it seems to me that the

P. Veratri Duby is a genuine *Puccinia*, and as such antedates the name of Niessl. The present species was described as *P. Veratri* Clinton in the Twenty-seventh Report N. Y. State Mus.

Nos. 1047 and 1048. As far as my experience goes, the uredo spores of *P. Prunorum* Lk. are much less common near Cambridge than the teleutospores, but in the Southern States they are common.

No. 1034. *Puccinia curtipes* Howe. This species has been supposed to be distinct from *P. Saxifragæ* Schlect. in having rather smaller teleutospores, which are covered with spiral striæ. In the specimen in Schweiz. Krypt., no. 711, which is named *P. Saxifragæ* Schlect., and quoted as such by Winter in Rabenhorst's Kryptogamenflora, the spores are distinctly striate, and the measurements are practically the same as in *P. curtipes*. Assuming, as we must, that the specimen in Schweiz. Krypt. is really *P. Saxifragæ*, I do not see how it is possible to keep *P. curtipes* distinct. No. 1049, on *Tiarella cordifolia*, certainly is not *P. Saxifragæ*, nor is it the same as the specimen in Herb. Curtis, no. 6146, which is described under the name of *P. Tiarellæ* B. & C. in Grevillea, Vol. III. p. 53. On this account the name *P. spreta* Pk. was adopted.

No. 1051. *Puccinia vexans* Farlow. A curious and perplexing species. This is not strictly, as the label would imply, a new species, for it has already been described by Peck under the name of *Uromyces Brandegei* in Bot. Gaz., Vol. IV. p. 127. It has been collected in several different localities in the Western States, but is a *Puccinia* rather than a *Uromyces*. It cannot, however, be called *P. Brandegei* (Pk.) because there is already another species of that name on *Corydalis*. I have received specimens from Mr. Brandegee, the original discoverer, and from several other botanists, and find that some of the sori contain two-celled spores, others only one-celled spores, and in other sori both kinds are intimately mixed. The two-celled spores are oval, obtuse at both ends, smooth or somewhat roughened in the upper part, and measure from $30–38\mu \times 19–24\mu$. The one-celled spores are dark brown, like the two-celled, obovate, distinctly papillate or roughened in the upper part, and of about the same dimensions as the two-celled, perhaps a trifle smaller. A species in which some of the sori contain only two-celled spores must certainly be held to be a *Puccinia*, and the perplexing question arises, Are the one-celled spores a unilocular form of teleutospores similar to what is known in *P. Cesatii* Schr., or are they the uredo spores of this species? I have not been able to find any other spores which represent the uredo of the species; and never having seen the unicellular spores in germination, there is, so far as we yet know, no reason why they may not be the uredo spores. On the other hand, their general appearance and the density of the cell wall would lead one to suppose that they were of a teleutosporic nature. Further conjecture is unnecessary, because, as the species is not at all rare in some localities, botanists who can examine the fungus on the spot ought to be able to ascertain whether the one-celled bodies produce promycelia or not, or else to discover the true uredo of the species. Although a *Uromyces* and a *Puccinia* may grow in close proximity to one another on the same leaf, I presume that almost no one would maintain that a *Uromyces* and a *Puccinia* could grow together in the same sorus, and assume that, in the present instance, we have to do with a distinct *Uromyces* and a distinct *Puccinia*.

No. 1052. *Puccinia Lantanæ* Farlow. As far as I can ascertain, an undescribed form, although it may prove to be the same as some tropical form which has escaped my notice. It is very common in Bermuda on *Lantana odorata* L. in January and February. It is infested by the parasite *Tubercularia persicina* Ditm., which gives a purple appearance to the sori in some of the specimens distributed.

PUCCINIA LANTANÆ Farlow. Sori round, naked, soon pulvinate, collected in irregular groups. Uredo unknown. Teleutospores germinating in the sorus, purple brown, slender-stalked, thin-walled, some two-celled, ovate, obtuse, slightly constricted at the septum, apex blunt or slightly mucronate, 26–38μ long by 19–26μ broad; mixed with one-celled, obovate, or irregularly elliptic spores, 23–27μ long by 15.5–20μ broad.

On leaves of *Lantana odorata* L. Bermuda.

The species is of interest in connection with *P. vexans*, as both species have in the same sori both one- and two-celled spores. In *P. Lantanæ*, however, the one-celled bodies are evidently teleutospores, as they produce promycelia while still attached, as may be seen in no. 1052.

Nos. 296–300. The generic names of these species should be corrected, although, with the exception of 299 and 300, the species are not new. 296. *Ascomyces Tosquinetii* and *Taphrina aurea* are both common, and the generic names are those adopted by Magnus in Hedwigia, September, 1874. The form of the last-named species, which occurs on the leaves of *Populus*, is unknown to me in Massachusetts.

No. 300. *Exoascus flavus* Farlow should not be confounded with *Exoascus Betulæ* Fuckel, although both occur on *Betula alba*. The latter is eight-spored, but the former is polysporic, not to mention other differences. *Ex. flavus* forms circumscribed yellow spots on the leaves during the month of June. The asci are borne between the cuticle and the epidermis, the cells of which become somewhat depressed as the fungus develops. The asci are very obtuse, often being nearly rectangular when seen in section, and they are very densely packed together. The mycelium, which is not easily seen except in thin stained sections, extends between the cuticle and epidermis, and, making its way between the cells of the latter, winds amongst the sub-epidermal parenchyma, but does not extend through the central part of the leaf. In sections, one sees the base of the asci abruptly drawn out into a short process, which is wedged in between the epidermal cells connecting with the mycelium below. It will be seen that the species occupies a position between the genus *Taphrina*, as represented by *T. aurea*, where the asci are polysporic and end in rootlike extremities which pass down between the epidermal cells, and the genus *Exoascus*, as represented by *Ex. Pruni*, where the asci are eight-spored and the mycelium is found throughout the leaves. Our species, however, is more nearly related to *Taphrina*, and the name should be changed to *Taphrina flava*.

TAPHRINA FLAVA Farlow. Mycelium between the cells of the outer part of the leaves. Asci on both sides of the leaves, between the cuticle and epidermis, densely packed, obtuse or truncate at both extremities, 38–57μ long by 20–23μ broad. Spores very numerous, bacterioid, hyaline, 3–7μ long by 1.5–2μ broad.

Forming bright yellow spots on leaves of *Betula alba*. Newton, Mass., June.

No. 298. I am unable to distinguish this form on *Prunus serotina* from the larger form on cultivated plums. An *Exoascus*, which is apparently the same as *Ex. Wiesneri* Rathay, is not unfrequently found with No. 298. It produces swellings and curling of the leaves, and enlargements of the younger twigs, recalling the deformities produced on peach leaves by *Ascomyces deformans*. The form of *Prunus* leaves which, as I have said, is probably *Ex. Wiesneri* (*Ex. deformans* f. *Cerasi* Fuckel), is common with us, but the distortions are not as marked as those figured by Rathay. The specific determination of the forms on leaves of *Rosaceæ* is difficult, and in No. 299 is a form on *Potentilla Canadensis* which was distributed under the name of *Ex. deformans* var. *Potentillæ*. The form is very common in Eastern Massachusetts, and is found during the whole summer, but especially in the latter part of June and July. It first appears as pale yellow spots on the leaves, which soon thicken and swell, becoming convex above and concave below, the color changing from yellow to a dark purple. The asci are clavate, 30–38μ long by about 6–8μ broad, and contain eight round or ovate spores 3–4μ in diameter. There is still another related species, if not a variety of *Ex. deformans* itself, which grows on *Rhus copallina* in Eastern Massachusetts. The leaves attacked become very much wrinkled and curled, and have a lurid purple color. The asci are somewhat stouter than in the form on *Potentilla*, being 24–30μ long by 11–15μ broad, and the spores are spherical and measure 3.5–4.5μ. If I am not mistaken, a similar form on an African *Rhus* has been reported by Magnus, but I am unable to refer to his description.

VIII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

RESEARCHES ON THE SUBSTITUTED BENZYL COMPOUNDS.

TWELFTH PAPER.

CERTAIN PARABROMBENZYL COMPOUNDS.

By C. Loring Jackson and G. T. Hartshorn.

Presented April 11th, 1883.

In a previous paper of this series a number of parachlorbenzyl compounds containing sulphur were described; in the following paper we have the honor of laying before the Academy a description of the corresponding compounds made from the parabrombenzylbromide.*

Parabrombenzylsulpho-acid, $C_6H_4BrCH_2SO_3H$.

The potassium salt of this substance was made by heating parabrombenzylbromide with an aqueous solution of neutral potassic sulphite in a flask with a return-cooler until the odor of the bromide disappeared. It was purified by crystallization from water, and dried first *in vacuo*, and afterwards at 110°, which showed that it contained no water of crystallization.

0.2230 g. of the substance gave, according to Carius, 0.1454 g. of argentic bromide.

0.2624 g. gave 0.1724 g. of argentic bromide, and 0.2140 g. of baric sulphate.

0.2224 g., after evaporation with sulphuric acid, gave 0.0688 g. of potassic sulphate.

	Calculated for $C_7H_6BrSO_3K$.	Found.	
Bromine	27.67	27.75	27.96
Sulphur	11.07		11.20
Potassium	13.50	13.89	

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* The results obtained will be found in tabular form at the end of the article.

It crystallizes in narrow plates, which not infrequently reach a length of over one centimeter, and are characterized by a well-marked cleavage at right angles to their longer axis. On one occasion rhombic forms similar to those of the sodium salt of the parachlorbenzylsulpho-acid were observed. It is not freely soluble in cold water or alcohol, but its solubility in each of these solvents is much increased by heat. The solubility in water at 18° was determined as follows: —

I. 3.2760 g. of the saturated solution gave 0.2016 g. of the salt.
II. 2.7104 g. gave 0.1689 g. of the salt.

Percentage of $C_6H_4BrCH_2SO_3K$ in aqueous solution saturated at 18°: —

I.	II.
6.15	6.25

To make the other salts of the sulpho-acid, the crude potassium salt was treated with a small quantity of plumbic acetate, to free it from bromide and sulphite; and, after filtering from the precipitate thus formed, the lead salt was thrown down by adding an excess of plumbic acetate, and purified by crystallization from water. It was then suspended in water, and treated with sulphuretted hydrogen to convert it into the free acid, which was used in the preparation of the following salts.

The *Calcium Salt* $(C_6H_4BrCH_2SO_3)_2Ca$, made by warming the acid with calcic carbonate, and purified by crystallization from water, was free from water of crystallization.

0.4472 g. of the salt dried at 110° gave 0.1096 g. of calcic sulphate.
0.2870 g. gave 0.0715 g. of calcic sulphate.

	Calculated for $(C_7H_6BrSO_3)_2Ca$.	Found.	
Calcium	7.41	7.21	7.33

The salt crystallizes in long colorless plates, and is freely soluble in water.

The *Barium Salt* $(C_6H_4BrCH_2SO_3)_2BaH_2O$ was made from the acid with baric carbonate, and purified by crystallization from water.

0.4300 g. of the salt dried *in vacuo* lost, when heated to 110°, 0.0124 g. of water.

0.4396 g. lost 0.0123 g. of water.

	Calculated for $(C_7H_6BrSO_3)_2BaH_2O$.	Found.	
Water	2.75	2.88	2.80

0.1630 g. of dried salt gave 0.0592 g. of baric sulphate.
0.3625 g. gave 0.1314 g. of baric sulphate.

	Calculated for $(C_7H_6BrSO_3)_2Ba$.	Found.	
Barium	21.50	21.35	21.31

It crystallizes in stellate groups of white needles, and is slightly deliquescent. Its solubility in water was determined as follows: —

I. 4.0670 g. of the solution saturated at 18° gave 0.1649 g. of the salt.

II. 4.1510 g. gave 0.1679 g. of the salt.

Percentage of $(C_6H_4BrCH_2SO_3)_2Ba$ in aqueous solution saturated at 18°: —

I.	II.
40.55	40.46

The *Lead Salt* $(C_6H_4BrCH_2SO_3)_2Pb$, made and purified as already described, was free from water of crystallization.

0.3144 g. of the salt dried at 110° gave on combustion 0.2709 g. of carbonic dioxide, and 0.0481 g. of water.

0.2988 g. of the salt gave 0.1297 g. of plumbic sulphate.

	Calculated for $(C_7H_6BrSO_3)_2Pb$.	Found.
Carbon	23.76	23.51
Hydrogen	1.69	1.70
Lead	29.28	29.66

It crystallizes in radiating groups of long white needles. Its solubility in water was determined as follows: —

I. 4.3370 g. of the solution saturated at 18° gave 0.0873 g. of the salt.

II. 3.4536 g. gave 0.0691 g. of the salt.

Percentage of $(C_6H_4BrCH_2SO_3)_2Pb$ in aqueous solution saturated at 18°: —

I.	II.
2.01	2.00

The *Chloride* of the *Sulpho-acid* $C_6H_4BrCH_2SO_2Cl$ was made by grinding the dry potassium salt in a mortar with phosphoric pentachloride, and finishing the reaction by a gentle heat. The substance was precipitated on the addition of water as an oil, which solidified on standing, and was purified by crystallization from ether or ligroine. It was dried *in vacuo* and analyzed.

0.2460 g. of substance gave, by the method of Carius, 0.3000 g. of the mixture of argentic chloride and argentic bromide, and 0.2028 g. of baric sulphate.

	Calculated for $C_7H_6BrSO_2Cl$.	Found.
Chlorine and Bromine	42.85	42.50
Sulphur	11.87	11.35

It crystallizes in small white prisms with a peculiar smell, similar to that of parabrombenzylbromide; but when cold it does not attack the mucous membrane, and when warmed only in a very much less degree than any of the brombenzylbromides. It melts at 115°, is essentially insoluble in water, and but slightly soluble in cold alcohol, ligroine, carbonic disulphide, and glacial acetic acid, freely soluble in all these solvents when hot, and in benzol and ether even in the cold.

Parabrombenzylsulphide, $(C_6H_4BrCH_2)_2S$.

This substance was made by boiling parabrombenzylbromide with an alcoholic solution of sodic sulphide; the reaction takes place very easily. The product obtained by distilling off part of the alcohol and precipitating with water was purified by crystallization from alcohol. Dried *in vacuo* it gave the following results on analysis: —

I. 0.1768 g. of substance gave, according to Carius, 0.1780 g. of argentic bromide.

II. 0.1807 g. gave 0.1828 g. of argentic bromide and 0.1057 g. of baric sulphate.

III. 0.2284 g. gave 0.1368 g. of baric sulphate.

	Calculated for $(C_7H_6Br)_2S$.	Found.		
		I.	II.	III.
Bromine	43.01	42.85	43.06	
Sulphur	8.60		8.04	8.23

Properties. — It crystallizes in large thin plates, apparently rhombic crystals, which have a tendency to turn brown in the air; the odor is aromatic, and not especially disagreeable; it melts at 58°–59°; is essentially insoluble in water, soluble with difficulty in cold alcohol, ligroine, or glacial acetic acid, but freely in each of these solvents when hot, and in ether, benzol, or carbonic disulphide.

Parabrombenzylsulphone, $(C_6H_4BrCH_2)_2SO_2$, was made from the sulphide by dissolving it in glacial acetic acid, and adding the calculated amount of chromic anhydride also dissolved in glacial acetic acid. After the action had ceased, the substance was precipitated with water, and purified by crystallization from alcohol. It was analyzed after drying at 100°.

0.1674 g. of substance gave by the method of Carius 0.1556 g. of argentic bromide and 0.0991 g. of baric sulphate.

	Calculated for $(C_7H_6Br)_2SO_2$.	Found.
Bromine	39.60	39.56
Sulphur	7.92	8.13

It crystallizes in white needles, with a slight not unpleasant smell; melts at 189°, and is essentially insoluble in water, soluble only to a slight extent in cold alcohol, benzol, ligroine, and glacial acetic acid, freely soluble in all these solvents when hot, and in ether and carbonic disulphide whether cold or hot.

Parabrombenzylmercaptan, $C_6H_4BrCH_2SH$.

This substance was made by the action of parabrombenzylbromide on an alcoholic solution of potassic sulphydrate. The action took place very easily, and the product fell as an oil on the addition of water to the alcoholic solution. It was purified by distillation with steam, and solidified to a white crystalline mass after standing some time. It had a disagreeable odor, and melted at 25°, but we cannot be perfectly certain that this is the true melting-point, on account of its strong tendency to pass into the disulphide on exposure to the air. The number given above, however, cannot be far from the correct one, as the sample was treated with zinc and sulphuric acid immediately before taking the melting-point. It dissolves easily in all the common solvents with the exception of water and glacial acetic acid. It did not seem worth while to analyze the free mercaptan, as the results obtained from it are almost identical with those from its principal impurity, the disulphide; but instead of this, we determined its nature much more satisfactorily by converting it into the mercaptid, which was then analyzed.

Parabrombenzylmercaptid, $(C_6H_4BrCH_2S)_2Hg$.

This substance was made by adding yellow mercuric oxide to the mercaptan suspended in water; after the action had ceased, the insoluble residue was purified by crystallization from boiling alcohol, and dried at 100°.

0.2623 g. of substance gave on precipitation with sulphuretted hydrogen 0.1016 g. of mercuric sulphide.

	Calculated for $(C_7H_6BrS)_2Hg$.	Found.
Mercury	33.11	33.38

It crystallizes from boiling alcohol as a light white feathery mass with a pearly lustre. It does not melt, but is decomposed and blackened at a high temperature, is essentially insoluble in water, very slightly soluble in cold alcohol, benzol, or glacial acetic acid, freely soluble in hot alcohol (the solution becomes nearly solid on cooling) and benzol, less so in hot glacial acetic acid, but freely in ether and carbonic disulphide.

Parabrombenzyldisulphide, $(C_6H_4BrCH_2)_2S_2$.

This substance was made from the mercaptan by exposure to the air, and also by acting on the parabrombenzylbromide with an alcoholic solution of sodic disulphide; the product precipitated with water was purified by crystallization from alcohol, and dried *in vacuo*.

0.1600 g. of the substance gave by the method of Carius 0.1487 g. of argentic bromide and 0.1838 g. of baric sulphate.

	Calculated for $(C_7H_6Br)_2S_2$.	Found.
Bromine	39.60	39.57
Sulphur	15.84	15.78

It crystallizes in radiating groups of white needles, and has a not unpleasant aromatic smell; melting-point, 87°–88°. It is essentially insoluble in water, slightly soluble in cold alcohol, and almost insoluble in cold glacial acetic acid, but freely soluble in both these solvents when hot, and in ether, benzol, and carbonic disulphide.

The following table gives the formulas and melting-points of the substances described in this paper.

Name.	Formula.
Parabrombenzylsulpho-acid	
Potassium Salt*	$C_6H_4BrCH_2SO_3K$
Calcium Salt	$(C_6H_4BrCH_2SO_3)_2Ca$

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* The solution saturated at 18° contains 6.20 per cent of the salt.

Name.	Formula.	Melting-point.
Barium Salt *	$(C_6H_4BrCH_2SO_3)_2BaH_2O$	
Lead Salt †	$(C_6H_4BrCH_2SO_3)_2Pb$	
Chloride	$C_6H_4BrCH_2SO_2Cl$	115°
Parabrombenzylsulphide	$(C_6H_4BrCH_2)_2S$	58°–59°
Parabrombenzylsulphone	$(C_6H_4BrCH_2)_2SO_2$	189°
Parabrombenzylmercaptan	$C_6H_4BrCH_2SH$	25°
Parabrombenzylmercaptid	$(C_6H_4BrCH_2S)_2Hg$	
Parabrombenzyldisulphide	$(C_6H_4BrCH_2)_2S_2$	87°–88°

* The solution saturated at 18° contains 40.50 per cent of the salt.

† The solution saturated at 18° contains 2.00 per cent of the salt.

IX.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

A NEW METHOD OF PREPARING BORNEOL FROM CAMPHOR.

By C. Loring Jackson and A. E. Menke.

Presented June 13th, 1883.

The natural borneol (Borneo camphor), obtained from the *Dryobalanops Camphora,* is brought from the East so rarely that specimens of it can be obtained in this country or in Europe only with the greatest difficulty; most chemists, who have studied this substance, have confined their attention therefore to the borneol obtained from ordinary camphor, which has been proved to be identical * with the natural product.

So far as we can find, there are but two methods of making borneol from camphor, — one by the action of potassic hydrate, which is due to Berthelot,† the other that of Baubigny,‡ consisting in treating camphor with sodium, and separating the sodium camphor from the sodium borneol by carbonic dioxide. Both leave much to be desired, since the product of the first is a mixture of camphor and borneol, which must be purified by treatment with stearic acid, and according to Kachler § the yield is very small, while the second yields pure borneol, it is true, but theoretically only one half of the camphor can be converted into borneol, although an amount of sodium is required which corresponds to the whole weight of camphor used.

In the course of some experiments on camphor, which led to no result so far as their main object was concerned, it was necessary for us to become acquainted with the reduction of camphor; but, to our great surprise, we were unable to find any description of experiments on this subject, unless the statement in Beilstein's *Handbuch der Organischen Chemie*, page 1763, that sodium amalgam does not act on camphor, comes under this head. We were compelled, therefore, to experiment ourselves, with the following result. 25 g. of camphor, melting at 175°, were dissolved in moist toluol, and sodium and water added at intervals, until a sample showed the melting-point of borneol, 197°–198°; the toluol was then driven off by heat, and a yellowish white mass obtained, with the smell at once like camphor and pepper, described as that of borneol. It was purified by sublimation, and analyzed with the following results: —

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* Kachler. Wien Acad. Ber. (2 Abth.), 78, July.

† Ann. Chim. Phys., ser. 3, lvi. p. 78.

‡ Ibid., ser. 4, xix. p. 221.

§ Ann. Chem. Pharm., clxiv. p. 75.

0.1642 g. of substance gave 0.4700 g. of carbonic dioxide, and 0.1772 g. of water.

	Calculated for $C_{10}H_{18}O$.	Found.
Carbon	77.93	78.07
Hydrogen	11.69	11.98

The substance is borneol, therefore, and the reduction of the camphor takes place, as was to be expected, according to the reaction.

$$\underset{\text{Camphor.}}{C_{10}H_{16}O} + H_2 = \underset{\text{Borneol.}}{C_{10}H_{18}O.}$$

The ease with which borneol was formed in this experiment led us to the following method for making borneol from camphor, which gives essentially the theoretical yield of nearly pure borneol with remarkably little trouble.

It consists in dissolving the camphor in about ten times its weight of common alcohol, and adding one third* more than the amount of sodium calculated from the reaction. The sodium is added in pieces of somewhat less than a gramme at a time, and in working with quantities not over ten grammes the action can be carried on in an open flask without cooling. As soon as all the sodium has disappeared, which takes less than three quarters of an hour with ten grammes of camphor, part of the alcohol is distilled off, and water added, which precipitates crude borneol. This is freed from sodic hydrate by washing with water; after which one crystallization from the smallest possible amount of hot alcohol is sufficient to raise its melting-point to 197°, that of borneol. In this way 10 g. of camphor yielded 9.5 g.

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* Probably a smaller excess of sodium would be sufficient.

of the crude borneol, instead of 10.1 g., — that is, 94 per cent of the theory; whereas, according to Baubigny's method, 4 g. of sodium, the amount which yielded 9.5 g. of borneol in our process, would have given only 6.6 g.

Our method, therefore, is superior to the other two in economy, as well as in the ease and speed with which it can be conducted.

X.

CONTRIBUTIONS TO AMERICAN BOTANY.

BY SERENO WATSON.

Presented May 29th, 1883.

1. *List of Plants from Southwestern Texas and Northern Mexico, collected chiefly by Dr. E. Palmer in* 1879–80.— II. *Gamopetalæ to Acotyledones.*

[Continued from Vol. XVII., page 361.]

VIBURNUM PRUNIFOLIUM, Linn. Kendall or Wilson County, Texas (387).

VIBURNUM MEMBRANACEUM, Benth. & Hook. Caracol Mountains, Coahuila (388).

SYMPHORICARPUS MICROPHYLLUS, HBK. A pubescent form, from the Sierra Madre, south of Saltillo (2118), and wholly glabrous, from Lerios in the high mountains east of that city (390); 296 Parry & Palmer.

LONICERA ALBIFLORA, Torr. & Gray. In the Sierra Madre, south of Saltillo (389).

LONICERA PILOSA, Willd. Sparingly collected in the same region; mountains near San Luis Potosi (733 Schaffner); Guanajuato (Dugès); 297 Parry & Palmer. The calyx-limb is usually glandular-hispid and the corolla villous. Dugès' specimen is glabrous throughout and probably represents *L. tubulosa*, Benth. All have the interior of the corolla-tube villous. *L. Moçiniana*, DC., is doubtless *L. involucrata*, Banks.

CEPHALANTHUS OCCIDENTALIS, Linn. At Uvalde, Texas (391).

BOUVARDIA ANGUSTIFOLIA, HBK. (?) In the mountains east of Saltillo (391). Apparently the same as 47, 316 and 650 of Gregg's collection, 236 Wright (referred to *B. hirtella*), and Eaton & Edward's specimens from near Monterey (referred to *B. triphylla*). The specimens collected in Arizona by Wright (1116, in part), Rothrock (479), Lemmon (167), and Pringle (distributed as *B. Jacquini*), may be the same, but are somewhat more glabrous, the leaves broader, and the corolla more elongated. The species of this genus are very poorly defined and greatly need revision.

BOUVARDIA TRIPHYLLA, Salisb. At Soledad, Coahuila (2091), a form with the acuminate lanceolate leaves in fours. Nearly the same as 940 Thurber, from Sonora, and specimens collected by Graham at Tlalpùjahua, and probably DeCandolle's *B. quaternifolia*. A single specimen with leaves in threes was found in the Caracol Mountains, having the corolla-lobes unusually long (2 lines or more).

BOUVARDIA HYPOLEUCA, Benth. In sandy localities near Morales, San Luis Potosi (712 Schaffner); 298 Parry & Palmer.

OLDENLANDIA OVATA. Annual, low, weak and slender, diffusely branching: leaves ovate to ovate-lanceolate, more or less abruptly contracted into a narrow petiole, acute, glabrous or slightly pubescent, 2 to 5 lines long: pedicels axillary and terminal, 2 to 6 lines long: calyx-lobes broad; corolla 1 to 1½ lines long: capsule hemispherical, rounded at base, not exceeding the calyx-teeth: seeds numerous, angled.— At Guajuco, Nuevo Leon (399); 200 Ervendberg, and 676½ Parry & Palmer. Differing from *O. microtheca* in its foliage and laxer habit, its smaller flowers not paniculate, the broader and obtuser calyx-teeth, and more numerous, smaller and less flattened seeds.

HOUSTONIA ANGUSTIFOLIA, Michx. A tall diffusely branched form from Georgetown, Texas (396), and from Monterey, Nuevo Leon (2116). 614 Schaffner, from the San Miguelito Mountains, is a low form with rather broad leaves. — Var. SCABRA, from the Caracol Mountains (410), is somewhat scabrous, and the short corolla is hirsute in bud toward the apex; capsules large.

HOUSTONIA LONGIPES. Annual, slender, diffusely branched, glabrous, the stems nearly terete: leaves revolute-filiform, 3 to 6 lines long: flowers on slender elongated pedicels (3 to 12 lines long): calyx a line long or less, with narrow lobes; corolla 3 lines long, with very slender tube and broad limb pubescent within: capsule short, not exceeding the calyx, round-ovate, very abruptly contracted at base, few- (about 10-) seeded. — From the mountains northeast of Monclova, Coahuila (394), and from Monterey, Nuevo Leon (395), and collected also by Dr. Gregg at Cerralbo. It has the habit of *H. asperuloides*, but the capsule is very different.

HOUSTONIA PALMERI, Gray in Proc. Amer. Acad. 17. 202. At Lerios (397) and in the mountains east of Saltillo (2117), and in the Sierra Madre, south of Saltillo (398).

Houstonia acerosa, Gray, l. c., 203. (*Hedyotis acerosa*, Gray. *Mallostoma acerosa*, Hemsl.) In the Caracol Mountains, at Soledad (401), and at Juraz, Coahuila (402). Also a form with broader leaves, and more conspicuous stipules uniting their bases, from the Sierra Madre, south of Saltillo (400), and from the mountains eastward (403); 302 Parry & Palmer.

Houstonia fasciculata, Gray, l. c. In the mountains northeast of Monclova (404), and at Saltillo, Coahuila (406).

Basanacantha (?) reticulata. A low stout unarmed shrub, the leaves and younger branches densely covered with a short spreading pubescence: leaves ovate to oblong-ovate or oblanceolate, obtuse or acutish, petiolate, 1 to 3 inches long, prominently reticulate-veined beneath; stipules submembranous, broadly triangular-lanceolate: flowers diœcious, glabrous, the staminate nearly sessile in short axillary corymbs, the pistillate solitary, terminal on short branchlets: staminate calyx very short (1½ lines long), the linear teeth exceeding the campanulate tube; corolla white, 6 to 9 lines long, the narrow tube exceeding the lobes; stamens 5, very short in the glabrous throat; style of the abortive ovary equalling the tube, 2-cleft: corolla of fertile flower unknown; the globose ovary crowned by the five persistent lanceolate calyx-teeth; fruit 9 lines in diameter, 2-celled, the numerous horizontal seeds immersed in the pulpy placentæ. — At San Lorenzo de Laguna, Coahuila (393). A peculiar species, probably to be referred to this genus, which however is scarcely distinct from *Randia*.

Randia Xalapensis, Mart. & Gal. At Guajuco, Nuevo Leon (158).

Diodia teres, Walt. At Sutherland Springs, Texas (409).

Diodia prostrata, Swartz, var. longiseta, DC. In San Luis Potosi Valley (1056 Schaffner, in part), and in the Morales Mountains (839 Schaffner); 303 and 304 Parry & Palmer. Probably distinct from the West Indian form.

Diodia tricocca, Torr. & Gray. At Sutherland Springs, Texas (408), and at Corpus Christi, near the beach (1186); also at Monterey, Nuevo Leon (1187).

Diodia tetracocca, Hemsl. Diag. Pl. Nov. 2. 32, and Bot. Biol. Centr.-Amer. 2. 56, t. 40, fig. 10–15. In San Luis Potosi Valley (1056 Schaffner, in part), and in the San Miguelito Mountains (838 Schaffner).

Mitracarpium breviflorum, Gray. In San Luis Potosi Valley (1035 Schaffner); 305 Parry & Palmer.

SPERMACOCE PODOCEPHALA, Benth. At Corpus Christi, Texas (470), and at San Luis Potosi (836 and 1057 Schaffner); 307 Parry & Palmer, and 100 Bourgeau, the latter referred by Hemsley to *S. verticillata*, which is a stouter woody-based species, with the flowers in close verticils as well as in terminal heads.

SPERMACOCE SUBULATA, Pav. At San Luis Potosi (837 Schaffner); 231½ and 306 Parry & Palmer.

RICHARDSONIA SCABRA, St. Hil. At Lamar, on Copano Bay, Texas (407).

GALIUM PROLIFERUM, Gray. Guajuco, Nuevo Leon (411).

GALIUM UNCINULATUM, DC. At Guajuco, Nuevo Leon (412), and near Morales, San Luis Potosi (840 Schaffner, and 179 of his previous collection), and the same as Botteri's Orizaba specimens under several numbers (188, 945, and 1174 in Herb. Gray). The stem is often nearly glabrous throughout. — Var. OBSTIPUM. (*G. obstipum*, Schlecht.) More pubescent throughout. From Lerios (413), the Caracol Mountains (414), and Saltillo. This form is also common in Texas. 886 Ghiesbreght, referred to the Peruvian *G. canescens*, is the same.

GALIUM MEXICANUM, HBK. Near Guanajuato (Dugès). *G. leucotrichum*, Hemsl., appears to be identical with *G. hypadenium*, Schauer.

GALIUM ASCHENBORNII, Schauer. In the San Miguelito Mountains, San Luis Potosi (841 Schaffner).

GALIUM MICROPHYLLUM, Gray. At Soledad (415) and at Lerios, Coahuila, and near Morales, San Luis Potosi (492^a Schaffner); 309 and 310 Parry & Palmer.

GALIUM POLYPLOCUM. (*Relbunium polyplocum*, Hemsl. Diag. Pl. Nov. 3. 53, and Bot. Biol. Centr.-Amer. 2. 63.) Near Morales, San Luis Potosi (842 Schaffner); 308 Parry & Palmer.

PHYLLACTIS PRATENSIS, Benth. & Hook. At Morelia, Guanajuato (Dugès); popularly known as "Ucuares," and the tuberous root a favorite article of food.

VALERIANA TOLUCANA, DC. In the Sierra Madre, south of Saltillo (416); 312 Parry & Palmer.

VALERIANA SORBIFOLIA, HBK. About San Luis Potosi (107 Schaffner), and Guanajuato (Dugès); 311 and 1071 Parry & Palmer. 2133 Seemann, from the Sierra Madre, is the same.

The following determinations of the *Compositæ* of Dr. Palmer's collection are by Dr. Gray. For his descriptions of the new species, and for other notes, reference is made to a subsequent article in this volume.

Vernonia Lindheimeri, Gray. At Uvalde, Texas (421).

Vernonia Ervendbergii, Gray, Proc. Amer. Acad. 17. 203. At Soledad, Coahuila (750).

Vernonia altissima, Nutt., var. grandiflora, Gray. At Sutherland Springs, Texas (751).

Vernonia angustifolia, Michx., var. Texana, Torr. & Gray. In Western Texas (752).

Vernonia Greggii, Gray, var. Palmeri, Gray, l. c. 204. At Lerios, Coahuila (753).

Vernonia Schaffneri, Gray, l. c. Mountains near Morales, San Luis Potosi (347 Schaffner).

Ageratum corymbosum, Zucc. At Saltillo (428), and a variety at Monclova, Coahuila (427).

Stevia salicifolia, Cav. In Coahuila (431); 321 Parry & Palmer.

Stevia Berlandieri, Gray. At Guajuco, Nuevo Leon (432).

Stevia Eupatoria, Willd. (Including *S. purpurea*, Lag.) At Lerios, Coahuila (433, 433^a).

Stevia paniculata, Lag. At Parras, Coahuila (439).

Eupatorium serotinum, Michx. At Sutherland Springs, Texas (423), and in Mexico (424).

Eupatorium betonicum, Hemsl. At Monclova, Coahuila (425).

Eupatorium cælestinum, Linn. At Georgetown, Texas (426).

Eupatorium incarnatum, Walt. In the Caracol Mountains, Coahuila (429).

Eupatorium dissectum, Gray. In the Sierra Madre, south of Saltillo (430).

Eupatorium azureum, DC. At Guajuco (434), and Monterey, Nuevo Leon (437, 438); 341 Parry & Palmer. The Monterey specimens, like those of Gregg's early collection (52), exactly match 1380 Berlandier, upon which *E. azureum* was founded. Upon Berlandier's ticket in herb. DC. "flores azurei" is written, hence the specific name. But Gregg noted the flowers as "purplish," and Palmer (upon the Guajuco specimen, which is evidently a form of the same) as "creamy white."

Eupatorium altissimum, Linn. At Lamar, on Copano Bay, Texas (435).

EUPATORIUM PETIOLARE, Moç. At Monterey, Nuevo Leon (440).

EUPATORIUM (PHANEROSTYLIS) COAHUILENSIS, Gray, Proc. Am. Acad. 17. 205. In the Sierra Madre, south of Saltillo (453).

EUPATORIUM (HEBECLINIUM) ——? Mexico, locality uncertain (2080).

EUPATORIUM ——? An uncertain ageratoid species. At Saltillo, Coahuila (436).

MIKANIA SCANDENS, Willd. In Southwestern Texas (441).

BRICKELLIA ODONTOPHYLLA, Gray, l. c. 206. In the Sierra Madre, south of Saltillo (442).

BRICKELLIA CYLINDRACEA, Gray, var. LAXA, Gray, l. c., 207. At Georgetown (446), and a more branched form at Bluffton, Texas (445).

BRICKELLIA RIDDELLII, Gray. At Georgetown (448), and Uvalde, Texas (449).

BRICKELLIA LACINIATA, Gray. In the mountains east of Saltillo, Coahuila (450).

BRICKELLIA COULTERI, Gray. With entire leaves. At Parras, Coahuila (451).

BRICKELLIA PALMERI, Gray, probably. Mexico, locality uncertain (2079).

BARROETTEA SUBULIGERA, Gray, Proc. Am. Acad. 15. 29, and 17. 205. At Soledad, Coahuila (452).

KUHNIA EUPATORIOIDES, Linn. At San Antonio and other localities in Western Texas (444, 447), and a broad-leaved form (443).

KUHNIA ROSMARINIFOLIA, Vent. At several localities in Western Texas and Coahuila (454, 455, 456, 457).

LIATRIS PUNCTATA, Hook. In the Caracol Mountains (418), at Monclova (419), and Juraz, Coahuila (420); 1085 Parry & Palmer.

GYMNOSPERMA CORYMBOSUM, DC. At various localities in Western Texas and Mexico (458, 459, 461, 464, 465).

GUTIERREZIA MICROCEPHALA, Gray. At San Lorenzo de Laguna (460), and at Saltillo, Coahuila (463).

GUTIERREZIA TEXANA, Torr. & Gray. At San Antonio, Texas (462, 466).

GRINDELIA ARIZONICA, Gray, l. c. 208. In Coahuila (467).

GRINDELIA SQUARROSA, Dun. (?) At Sutherland Springs, Texas (468). Too immature for determination; perhaps *G. lanceolata*, Nutt.

GRINDELIA INULOIDES, Willd. At Lerios, Coahuila (471). Also var. MICROCEPHALA, Gray, in Southwestern Texas (469, 2078).

GRINDELIA COSTATA, Gray, l. c. 208. In Mexico (472).

HETEROTHECA LAMARCKII, DC. (*H. scabra*, DC.) At Laredo, on the Rio Grande, Texas (491), and at Monterey, Nuevo Leon (481).

HETEROTHECA CHRYSOPSIDIS, DC. (?) At Saltillo, Coahuila (492).

CHRYSOPSIS VILLOSA, Nutt., var. CANESCENS, Gray. In Western Texas (482), and a form also from Lerios, Coahuila (480).

CHRYSOPSIS PILOSA, Nutt. Southwestern Texas (2077).

XANTHISMA TEXANUM, DC. In Western Texas (746, 747).

APLOPAPPUS RUBIGINOSUS, Torr. & Gray, var. (*A. phyllocephalus*, DC.) At Corpus Christi, Texas (473).

APLOPAPPUS SPINULOSUS, DC. At Monterey, Nuevo Leon (474), and Soledad, Coahuila (477).

APLOPAPPUS DIVARICATUS, Gray. From several localities in Southwestern Texas (475, 476, 478, 479).

BIGELOVIA VENETA, Gray. At Parras, Coahuila (483); 375 Parry & Palmer.

BIGELOVIA DRUMMONDII, Gray, var. (?) At Guadalupe, Texas (486), and at Soledad, Coahuila (485). The specimens may belong to *B. Wrightii*, Gray.

BIGELOVIA CORONOPIFOLIA, Gray. At Eagle Pass, Texas (487).

SOLIDAGO CANADENSIS, Linn., var. CANESCENS, Gray. At San Antonio, Texas (488).

SOLIDAGO NEMORALIS, Ait. Southwestern Texas (2076). Also var. INCANA, Gray. In the Sierra Madre, south of Saltillo (489); a rigid form.

SOLIDAGO VELUTINA, DC. At Parras, Coahuila (490).

APHANOSTEPHUS HUMILIS, Gray. Between the Frio and Nueces Rivers, Texas (494), and at Monclova, Coahuila (529); 378 Parry & Palmer.

APHANOSTEPHUS ARKANSANUS, Gray. At Sutherland Springs (497), and at Bluffton, Texas (523). Also var. HALLII, Gray; at Corpus Christi, Texas (502).

APHANOSTEPHUS RAMOSISSIMUS, DC. In Southwestern Texas (521), and at Juraz, Coahuila (532).

TOWNSENDIA MEXICANA, Gray. At Saltillo, Coahuila (499).

CHÆTOPAPPA (DISTASIS) MODESTA, Gray. At various localities in Mexico (500, 503 to 508).

PSILACTIS BREVILINGULATA, Schultz Bip. In the Sierra Madre, south of Saltillo (515, 528).

DICHÆTOPHORA CAMPESTRIS, Gray. At Monterey (501).

ASTER ERICÆFOLIUS, Rothr. In the Sierra Madre, south of Saltillo (484). A very slender form.

ASTER PHYLLOLEPIS, Gray. Western Texas (498).

ASTER (ORTHOMERIS) PALMERI, Gray, Proc. Am. Acad. 17. 209. At Corpus Christi (509), and at Eagle Pass, Texas (516).

ASTER MULTIFLORUS, Ait. In Western Texas (517), and in Mexico (2075). Also a variety (*A. hebecladus*, DC.) at Uvalde (518).

ASTER DIVARICATUS, Nutt. At Sutherland Springs, Texas (519, 520, 522), and a large-leaved form at Saltillo, Coahuila (526).

ASTER DRUMMONDII, Lindl. In Western Texas (524, 525).

ASTER TANACETIFOLIUS, HBK. Locality uncertain (527).

ERIGERON DRYOPHYLLUS, Gray, l. c. 210. At Guajuco, Nuevo Leon (495).

ERIGERON PALMERI, Gray. A hirsute form, at Saltillo (496), and Lerios, Coahuila.

ERIGERON PUBESCENS, HBK. In Mexico (530, 531, 2074).

ERIGERON CANADENSIS, Linn. (*E. strictus*, DC.) In Western Texas (2073).

CONYZA SUBDECURRENS, DC. At Monclova (534), and in the mountains north of that place (533).

BACCHARIS TEXANA, Torr. & Gray. In Southwestern Texas (510, 511, 535, 536).

BACCHARIS PTERONIOIDES, DC. (*B. ramulosa*, Gray.) In Mexico (513, 514).

BACCHARIS BIGELOVII, Gray. In the Caracol Mountains, Coahuila (537).

BACCHARIS ANGUSTIFOLIA, Michx. In Western Texas (538), and at Parras (541, 542).

BACCHARIS GLUTINOSA, Pers. (*B. Alamani*, etc., DC.) At Laredo, Texas (539), and at Parras, Coahuila (540).

PLUCHEA CAMPHORATA, DC. At Sutherland Springs, Texas (543), and in the mountains north of Monclova (544).

PLUCHEA ODORATA, Cass. At Monterey, Nuevo Leon (545).

PLUCHEA SUBDECURRENS, DC., var. CANESCENS, Gray. Same locality (546).

PTEROCAULON VIRGATUM, DC. At Sutherland Springs, Texas (422).

EVAX MULTICAULIS, DC. Between the Frio and Nueces Rivers, Texas (1146), and at Juraz, Coahuila (547).

GNAPHALIUM SPRENGELII, Hook. & Arn. At San Lorenzo de Laguna, Coahuila (548, 552).

Gnaphalium Wrightii, Gray, l. c. 214. West of San Antonio, Texas (549).

Gnaphalium decurrens, Ives. At Uvalde, Texas (550).

Gnaphalium oxyphyllum, DC. In the Sierra Madre, south of Saltillo (551); 417 Parry & Palmer.

Gnaphalium semiamplexicaule, DC. In the Caracol Mountains, Coahuila (553).

Gnaphalium purpurascens, DC. (*G. Schraderi*, DC., probably. *G. roseum*, HBK.?) In Coahuila (2071), and San Luis Potosi (223 Schaffner); 415 and 417½ Parry & Palmer.

Gnaphalium purpureum, Linn. In Mexico (2072).

Gnaphalium pannosum, Gray; *new sp.* San Luis Potosi (227 Schaffner); 420 Parry & Palmer.

Dicranocarpus parviflorus, Gray. At Monclova (641).

Melampodium cinereum, DC. In Southwestern Texas (555, 558). — Var. ramosissimum, Gray. (*M. ramosissimum*, DC.) At Laredo, on the Rio Grande (651), and other Texan localities (556, 557). — Var. argophyllum, Gray. In Mexico (2068).

Silphium asperrimum, Hook. At Georgetown, Texas (599).

Berlandiera tomentosa, Torr. & Gray, var. dealbata, Gray. In Western Texas (561).

Engelmannia pinnatifida, Torr. & Gray. In Mexico (562).

Parthenium incanum, HBK. (*P. ramosissimum*, DC.) At several localities in Mexico (563, 564, 565).

Parthenium argentatum, Gray. In Mexico (566, 646).

Parthenium lyratum, Gray, *ined.* In Mexico (647).

Parthenium confertum, Gray, Proc. Am. Acad. 17. 216. At Parras, Coahuila (648); 86 Gregg.

Iva angustifolia, Nutt. In Western Texas (567).

Iva ambrosiæfolia, Gray. In Mexico (573, 574).

Iva dealbata, Gray. At Soledad (737), and Monclova (738).

Hymenoclea monogyra, Gray. In Western Texas (568).

Ambrosia artemisiæfolia, Linn. In Mexico (569).

Ambrosia psilostachya, DC. In Mexico (570).

Ambrosia aptera, DC. In Western Texas (571).

Franseria tenuifolia, Gray. In Western Texas (572, 574).

Zinnia pauciflora, Linn. In Western Texas (574$^{\text{bis}}$, 575).

Zinnia juniperifolia, Gray. In the Sierra Madre, south of Saltillo (576). With leaves, heads, and rays larger than in Gregg's specimens, much larger than in the poor specimens of Berlandier.

Zinnia acerosa, Gray. In Coahuila (577, 578).

ZINNIA ANOMALA, Gray. Sierra Madre, south of Saltillo (581).

SANVITALIA ANGUSTIFOLIA, Engelm. At Parras (591), and a form with the chaff of the receptacle more cuspidate, at Saltillo (588).

HELIOPSIS PARVIFOLIA, Gray, a cinereous form. In the mountains east of Saltillo (586).

ECLIPTA ALBA, Hassk. (*E. erecta* and *E. prostrata*, Linn.) In Western Texas (582).

ZALUZANIA TRILOBA, Pers. At Parras, Coahuila (592).

ZALUZANIA MEGACEPHALA, Schultz Bip. (?) But quite different from *Z. angusta*, and the rays inclined to be sterile. Pubescence of inflorescence and lower surface of the upper leaves aurate, as noted by Palmer. In the Sierra Madre, south of Saltillo (734).

VARILLA MEXICANA, Gray. At Parras, Coahuila (680).

VARILLA TEXANA, Gray. At Eagle Pass, Texas (739).

GYMNOLOMIA TENUIFOLIA, Benth. & Hook. At Parras and other Mexican localities (620, 621, 622, 623).

SCLEROCARPUS UNISERIALIS, Benth. & Hook. In Western Texas (593, 594, 595), and Mexico (596).

TETRAGONOTHECA TEXANA, Engelm. & Gray. In Western Texas (583), at Soledad (2065), and mountains north of Monclova (559).

TETRAGONOTHECA LUDOVICIANA, Gray, var. REPANDA, Gray. West of San Antonio, Texas (560, 609).

BORRICHIA FRUTESCENS, DC. In Western Texas (587).

ZEXMENIA BREVIFOLIA, Gray. At Eagle Pass, Texas (624), and at Soledad, Coahuila (625).

ZEXMENIA HISPIDA, Gray. (*Z. Texana*, Gray.) In Western Texas (630), and at Soledad (631).

LEPACHYS PEDUNCULARIS, Torr. & Gray. Western Texas (718). A small form.

LEPACHYS COLUMNARIS, Torr. & Gray. Western Texas (719). Also var. PULCHERRIMA, Torr. & Gray, in Texas (720, 2085), and Mexico, a small and slender form (717).

VIGUIERA HELIANTHOIDES, HBK., var. (*V. laxa*, DC. *V. Texana*, Torr. & Gray.) Western Texas (603, 604), and in Mexico, a narrow-leaved form (614). The last is *V. brevipes*, DC.

VIGUIERA CANESCENS, DC. At San Lorenzo de Laguna, Coahuila (618).

VIGUIERA LINEARIS, Schultz Bip. (*Leighia linearis*, DC.) In Mexico (626).

HELIANTHUS ANNUUS, Linn. (*H. lenticularis*, Dougl.) In Mexico (600), and a depauperate form (2070).

HELIANTHUS MAXIMILIANI, Schrad. Localities uncertain (602, 2066).

HELIANTHUS LACINIATUS, Gray. At Parras (605), San Lorenzo de Laguna (606), and Saltillo, Coahuila (607).

HELIANTHUS DEBILIS, Nutt., var. CUCUMERIFOLIUS, Gray. Western Texas (608).

HELIANTHUS CILIARIS, DC., var. With linear leaves. At Juraz, Coahuila (616).

FLOURENSIA CERNUA, DC. In Mexico (740).

ENCELIA MEXICANA, Mart. In the Sierra Madre, south of Saltillo (493); 471 Parry & Palmer.

ENCELIA CALVA, Gray. At Bluffton (610), San Antonio (611), and Eagle Pass, Texas (613).

ENCELIA SUBARISTATA, Gray. At Guadalupe, Texas (612), and in the Caracol Mountains, Coahuila (615).

ENCELIA MICROPHYLLA, Gray. In Mexico (589).

HELIANTHELLA MEXICANA, Gray. In the Sierra Madre, south of Saltillo (601); a broader-leaved and more hispid form than the original specimens from San Luis Potosi. Collected also long ago by Gregg in the same district.

VERBESINA COAHUILENSIS, Gray; *new sp.* In the mountains east of Saltillo, Coahuila (584, 619).

VERBESINA WRIGHTII, Gray, var. In the Sierra Madre, south of Saltillo (585, 597), and at Parras, Coahuila (598).

VERBESINA ENCELIOIDES, Benth. & Hook. In Western Texas (617), and in Coahuila (2063, 2064).

VERBESINA STRICTA, Gray. (*Actinomeris stricta*, Hemsl. Bot. Biol. Centr.-Amer. 2. 186.) In the Sierra Madre, south of Saltillo (627), and at Lerios (628).

VERBESINA VIRGINICA, Linn. At San Antonio (731), and Guadalupe, Texas (732). Also var. PALMERI, Gray, at Soledad, Coahuila (733).

SYNEDRELLA VIALIS, Gray, Proc. Am. Acad. 17. 217. (*Calyptrocarpus vialis*, Less. *Oligogyne Tampicana*, DC. *Blainvillea biaristata*, DC.) In Western Texas (2069), and Mexico (590); 443 Parry & Palmer.

COREOPSIS CARDAMINEFOLIA, DC. At Corpus Christi, Texas (635).

THELESPERMA FILIFOLIUM, Gray. In Western Texas (636).

THELESPERMA SUBSIMPLICIFOLIUM, Gray. At Sutherland Springs, Texas (637), and in the Sierra Madre, south of Saltillo (638).

THELESPERMA GRACILE, Torr. & Gray. At Saltillo (639), and Parras, Coahuila (2061^{bis}).

BIDENS CHRYSANTHEMOIDES, Michx. At Uvalde, Texas (633).

BIDENS HETEROPHYLLA, Ort. At Parras, Coahuila (634).

GALINSOGA PARVIFLORA, Cav. At the same locality (652); a variety without pappus in the ray.

TRIDAX PROCUMBENS, Linn. In Mexico (629, 2061).

RIDDELLIA ARACHNOIDEA, Gray. In Mexico, localities uncertain (678, 679, 2082).

HYMENOPAPPUS FLAVESCENS, Gray. In the Sierra Madre, south of Saltillo (650).

HYMENOPAPPUS ARTEMISIÆFOLIUS, DC. At Uvalde (2081).

BAHIA ABSINTHIIFOLIA, Benth. In Coahuila and Nuevo Leon, a narrow-leaved form, answering to the original (674), and a slightly broader-leaved form (672, 673). Also var. DEALBATA, Gray, from near Monclova.

FLORESTINA TRIPTERIS, DC. In Western Texas (653), and Coahuila (654).

POLYPTERIS TEXANA, Gray. (*Palafoxia Texana*, DC.) In Western Texas (642, 644, 2060), and at Soledad, Coahuila (645).

POLYPTERIS HOOKERIANA, Gray. (*Palafoxia Hookeriana*, Torr. & Gray.) In Western Texas (655).

POLYPTERIS CALLOSA, Gray. (*Palafoxia callosa*, Torr. & Gray.) At Bluffton, Texas (656).

PALAFOXIA LINEARIS, Lag. At Monclova, Coahuila (643). Apparently an annual-rooted form.

SARTWELLIA MEXICANA, Gray; *new sp.* At Monclova and San Lorenzo de Laguna, Coahuila (683, 687).

FLAVERIA LONGIFOLIA, Gray. (*Gymnosperma* (?) *oppositifolium*, DC.) At Parras, Coahuila (681, 685); 498 Parry & Palmer. The specimens with smaller heads come very near *F. linearis*, Lag., of the coast of Cuba, the Bahamas, and Florida.

FLAVERIA CHLORÆFOLIA, Gray. At Juraz and Parras, Coahuila (682, 2083).

FLAVERIA ANGUSTIFOLIA, Pers. At San Lorenzo de Laguna, Coahuila (684). A low and narrow-leaved variety.

FLAVERIA (BROTEROA) REPANDA, Lag. Near Parras (686). Sometimes confounded with *F. Contrayerba.*

POROPHYLLUM FILIFOLIUM, Gray; *new sp.* In the Sierra Madre, south of Saltillo (688). The specimens may be found mixed with a little *Thelesperma subsimplicifolium.*

Porophyllum amplexicaule, Engelm. At Parras and Soledad, Coahuila (689).

Porophyllum scoparium, Gray. (*P. Greggii*, Gray, in part.) At Parras, Saltillo, and Monterey (690 to 694).

Porophyllum macrocephalum, DC. At Soledad (704).

Nicolletia Edwardsii, Gray. At Monclova, Coahuila.

Dysodia pubescens, Lag. In the Sierra Madre, south of Saltillo (579, 580).

Dysodia chrysanthemoides, Lag. At Saltillo (695).

Hymenatherum pentachætum, DC. (*H. Berlandieri*, DC.) Various forms. In Western Texas (697), and in Coahuila and Nuevo Leon (696, 698, 2084).

Hymenatherum Wrightii, Gray. At Sutherland Springs (699), and Corpus Christi, Texas (700).

Hymenatherum gnaphaliopsis, Gray. At Monterey, Nuevo Leon (707).

Hymenatherum (Aciphyllæa) acerosum, Gray. At Parras (709), and Saltillo (710); the latter with an unusual appearance, having rather long primary leaves, and hardly any in axillary fascicles.

Tagetes lucida, Cav. In Coahuila (705, 706).

Chrysactinia Mexicana, Gray. In the Sierra Madre, south of Saltillo (708, 711).

Pectis prostrata, Cav. At Monclova (640).

Pectis angustifolia, Torr. At Saltillo and Monclova, Coahuila (701, 702).

Helenium tenuifolium, Nutt. At Sutherland Springs, Texas (712). — Also var. badium, Gray, with purplish-brown instead of yellow disk. At Bluffton, Texas (716). First distributed in Hall's Texan collection (364), and recently collected by Reverchon, in Southwestern Texas, with most of the lower leaves pinnately parted.

Helenium elegans, DC. (*H. microcephalum*, var. *bicolor*, Torr. & Gray.) A form with rays all yellow. At Sutherland Springs, Texas (713). On full comparison this proves to be sufficiently distinct from *H. microcephalum*. It has rather smaller and more globose heads and a more hemispherical receptacle, as well as a shorter pappus.

Helenium amphibolum, Gray. At Parras (714). 523 Parry & Palmer has been wrongly referred to this species. One of our specimens is *H. Mexicanum*, HBK., the other is *H. ooclinium*.

Helenium ooclinium, Gray. At Monclova (715). 346 Schaffner, from San Luis Potosi, appears to be the same; but if so the character of the receptacle fails, for in this it is hemispherical, instead of ovate.

HELENIUM MICROCEPHALUM, DC. At Bluffton, Texas (735). Depauperate specimens, but answering to 1429 Berlandier.

AMBLYOLEPIS SETIGERA, DC. At Monterey, Nuevo Leon (724).

GAILLARDIA COMOSA, Gray; *new sp.* At Saltillo (721).

GAILLARDIA PULCHELLA, Foug. At Monterey, (722). And var. PICTA, Gray; at Corpus Christi, Texas (729).

GAILLARDIA PINNATIFIDA, Torr. At Parras (723). The long villi of the akene are in this species, as in *G. comosa* and *G. simplex*, inserted over the whole surface.

GAILLARDIA MEXICANA, Gray; *new sp.* In the Sierra Madre, south of Saltillo (725), and at Lerios, Coahuila, a dwarf subcaulescent form (726).

GAILLARDIA SIMPLEX, Scheele. (*Agassizia suavis*, Gray & Engelm.) At Saltillo and Monclova (727, 728, 2086).

GAILLARDIA LANCEOLATA, Michx. A depauperate slender form. At Sutherland Springs, Texas (730).

ACTINELLA (PLATYLEMA) PALMERI, Gray; *new sp.* At Saltillo (554).

ACTINELLA INSIGNIS, Gray; *new sp.* At Lerios, Coahuila (632).

ACTINELLA SCAPOSA, Nutt. At Monterey, Nuevo Leon. Also var. LINEARIS, Nutt., in Western Texas and Coahuila (657, 658, 659).

ACTINELLA LINEARIFOLIA, Torr. & Gray. In Coahuila and Nuevo Leon (670, 671, 677).

ACTINELLA ODORATA, Gray. At Laredo, Texas (742), and in Coahuila (741).

BAILEYA MULTIRADIATA, Gray. (*B. pluriradiata*, Gray.) In Coahuila (675, 676).

ARTEMISIA MEXICANA, Willd. At Soledad, Coahuila (736). A loosely paniculate form.

HAPLOESTHES GREGGII, Gray. In the mountains east of Saltillo (649).

SENECIO SALIGNUS, DC. At Parras, Coahuila, and in Nuevo Leon (743, 744); the last a slender form, the same as 1367 Berlandier, on which is founded *S. axillaris*, Klatt, in Abhandl. Nat. Gesell. Halle, 15. 13.

SENECIO LOBATUS, Pers. At Monclova (754). A slender depauperate form, the same as 1741 Berlandier, on which Klatt, l. c., founded his *S. imparipinnatus*.

SENECIO SANGUISORBA, DC. At Lerios, Coahuila (755).

SENECIO MADRENSIS, Gray; *new sp.* In the Sierra Madre, south of Saltillo (756).

SENECIO TOLUCCANUS, DC. In the same locality; a single specimen of a broad-leaved form, answering to one collected by Schaffner and so named by Schultz Bip.

CNICUS ALTISSIMUS, Pursh, var. FILIPENDULUS, Gray (?) At Parras (765).

CENTAUREA AMERICANA, Nutt. At Saltillo (766).

GOCHNATIA HYPOLEUCA, Gray. (*Moquinia hypoleuca*, DC.) At Laredo, on the Rio Grande (749), and at Parras, Coahuila (748).

CHAPTALIA NUTANS, Hemsl. In Mexico (764).

PEREZIA WRIGHTII, Gray. (*P. Coulteri*, Gray, in part.) At Parras (767), and in the mountains north of Monclova, Coahuila (768).

PEREZIA RUNCINATA, Lag. At Uvalde, Texas (769).

TRIXIS ANGUSTIFOLIA, DC. At Parras (745) and Soledad, Coahuila (2089); verging nearly to var. *latiuscula*, Gray.

RHAGADIOLUS HEDYPNOIDES, All. At Corpus Christi, Texas (2087). A waif.

HIERACIUM CREPIDISPERMUM, Fries. In the Sierra Madre, south of Saltillo (758).

HIERACIUM MEXICANUM, Less., var. NIVEOPAPPUM, Gray. In the same locality (757); 552 and 553 Parry & Palmer.

TARAXACUM OFFICINALE, Vill. In the mountains east of Saltillo, at Monterey (761), and at San Luis Potosi (382 Schaffner).

PYROPAPPUS MULTICAULIS, DC. At Saltillo, Coahuila (759), and a stouter more robust form at Monterey (760).

PINAROPAPPUS ROSEUS, Less. In the mountains south of Saltillo, at Monterey (762), and at San Luis Potosi (390 Schaffner).

LYGODESMIA GRANDIFLORA, Torr. & Gray. At Sutherland Springs, Texas (763).

LOBELIA LAXIFLORA, HBK., var. ANGUSTIFOLIA, DC. In the mountains about San Luis Potosi (738 Schaffner), and at Guanajuato (Dugès); 560 Parry & Palmer.

LOBELIA SPLENDENS, Humb. & Bonpl. At San Antonio (774) and Sutherland Springs, Texas (2090). — Var. FULGENS. (*L. fulgens*, Humb. & Bonpl.) The pubescent form, rather rarer and more restricted in its range. At Monterey (773).

LOBELIA FENESTRALIS, Cav. In the San Miguelito Mountains, San Luis Potosi, with larger flowers than usual (764 Schaffner), and at Guanajuato (Dugès); 558 Parry & Palmer.

LOBELIA GRUINA, Cav. Near Morales, San Luis Potosi (763 Schaffner); 559 Parry & Palmer.

LOBELIA CLIFFORTIANA, Linn., var. BRACHYPODA, Gray. At Monterey (772); the same as 419 and 1429 Wright, referred to *L. Berlandieri.* Also a low slender form with white flowers, from the same region (771). This species appears to be always glabrous.

LOBELIA BERLANDIERI, DC. At Monterey (770), at San Luis Potosi (119 Schaffner), and at Morales (737 Schaffner); 556 and 556½ Parry & Palmer. The same was collected also by Gregg at Monterey, and by Berlandier (3177) at Matamoros, and it is probably the same as Berlandier's 106 from Tampico, the original of the species. Puberulent and more or less hirsute toward the base with reflexed hairs, the stems low and lax, and the pedicels elongated.

HETEROTOMA LOBELIOIDES, Zucc. Mountains near Santa Maria del Rio, San Luis Potosi (736 Schaffner).

CAMPANULA ROTUNDIFOLIA, Linn. At Lerios, in the high mountains east of Saltillo (776).

ARBUTUS XALAPENSIS, HBK. (?) In the Sierra Madre, south of Saltillo (777), and at Lerios (778); 314 of Schaffner's previous distribution. The very young leaves are densely pubescent, becoming nearly glabrous and beneath somewhat glaucous. The young ovary is usually pubescent. *A. Texana*, Buckley (referred to *A. Menziesii*), is the same. *A. prunifolia*, Klotsch, is doubtless the same species, and probably also *A. prunifolia*, Lindl. It agrees more nearly, perhaps, with the description of *A. mollis*, HBK., than with that of *A. Xalapensis*, and is apparently identical with the plant formerly cultivated as *A. mollis* and figured in Bot. Mag. t. 4595. 562 Parry & Palmer, and 98 Schaffner from the San Miguelito Mountains, are very similar to this, but the leaves are mostly quite glabrous, as also the ovaries. *A. Menziesii*, Pursh, with larger wholly glabrous and very rarely serrulate leaves, and with the ovary always glabrous, appears to be confined to California and Oregon.

ARBUTUS GLANDULOSA, Mart. & Gal. In the San Rafael Mountains (99 Schaffner); 563 Parry & Palmer.

ARCTOSTAPHYLOS PUNGENS, HBK. In the Sierra Madre, south of Saltillo (779), at Lerios (780), and at Guanajuato (Dugès), where it is known as "Pinguica" and employed as a diuretic; 565 Parry & Palmer.

PLUMBAGO SCANDENS, Linn. At Guajuco, Nuevo Leon (2106); 240½ Parry & Palmer.

PLUMBAGO PULCHELLA, Boiss. Near San Luis Potosi (727 Schaffner), and at Guanajuato (Dugès) where it is known as "Tiricua"; 240 Parry & Palmer, referred to the last species.

ANAGALLIS ARVENSIS, Linn. At Saltillo (782), and about San Luis Potosi (141 Schaffner).

CENTUNCULUS MINIMUS, Linn. Near Morales, San Luis Potosi (124 Schaffner); 569½ Parry & Palmer.

SAMOLUS EBRACTEATUS, HBK. At Sutherland Springs, Texas (781); a low form with very broadly spatulate leaves and small white flowers. Also at Parras (783), a variety with large purple flowers. 569 Parry & Palmer is a very peculiar variety, with acutely oblanceolate and very narrowly petiolate leaves, and long acuminate calyx-teeth.

BUMELIA SPINOSA, DC. At Uvalde, Texas (156), and at Saltillo, Coahuila (786). Agreeing satisfactorily with the figure of Moçino & Sesse, and differing from *B. lanuginosa* in its more spinose branches, smaller leaves, and in the mottled seed slightly more narrowed at base. It extends into Arizona, where it has been collected by Lemmon and Pringle (distributed as *B. pauciflora*, Engelm.). A more canescent form, from Parras (787), with shorter pedicels and less pubescent calyx, is probably the same.

DIOSPYROS TEXANA, Scheele. From Uvalde, Texas (789), and Guajuco, Nuevo Leon (784); also staminate specimens from near Laredo, Texas (788).

MENODORA HETEROPHYLLA, Moric. At San Antonio (790) and Sutherland Springs, Texas (791).

MENODORA COULTERI, Gray. Locality not given; 300½ Parry & Palmer. 571 Parry & Palmer, referred to this species, is a dwarf small-flowered form of *M. helianthemoides* (570 Parry & Palmer), or closely allied to it, and the same as 44 Gregg.

MENODORA LONGIFLORA, Gray. In the mountains north of Monclova (792); both the usual glabrous form and a pubescent variety, the *M. pubens*, Gray. The two forms were also distributed by Wright under the same number (1695). At Juraz, Coahuila, specimens were collected with unusually short corollas, not exceeding an inch in length (794).

MENODORA SCABRA, Gray. At Juraz, on the Sabinas River, Coahuila (793).

MENODORA SCOPARIA, Engelm. Probably the same locality (795).

FRAXINUS CUSPIDATA, Torr. In the mountains east of Saltillo (796).

FRAXINUS PISTACIÆFOLIA, Torr. At Parras, Coahuila (797), with nearly the typical foliage though quite variable even in the same specimen. Other specimens from the same locality (798) have the leaves narrowly lanceolate, long-acuminate, attenuate at base, and coarsely serrate.

FRAXINUS VIRIDIS, Michx., var. BERLANDIERANA, Gray. At Monterey, Nuevo Leon; at San Luis Potosi (900 Schaffner); 572 Parry & Palmer.

FORESTIERA ANGUSTIFOLIA, Torr. With leaves varying in form and size; at Uvalde (801), Eagle Pass (802), Corpus Christi Bay (803), and near Laredo, Texas (804), and at Monterey, Nuevo Leon (799, 800).

THEVETIA YCCOTLI, DC., var. GLABRA, DC. At Guanajuato (Dugès); popularly known as "Frayle."

APOCYNUM CANNABINUM, Linn. In the Caracol Mountains, Coahuila (806); referred to *A. androsæmifolium*.

ECHITES (EUECHITES) COULTERI. Low (about a foot high), finely pubescent or becoming nearly glabrous: leaves oblong-lanceolate, narrow at base and rarely slightly cordate, acute, 1 to 1½ inches long, on very short petioles: inflorescence glabrous; peduncles shorter than the leaves, 2–7-flowered; bracts and calyx-lobes linear-subulate, acuminate, the latter nearly half the length of the corolla-tube and recurved; corolla 8 to 10 lines long, the lobes about equalling the cylindrical tube, which is pubescent within: anthers lanceolate, acuminate, cordate at base: follicles glabrous, 2 to 4 inches long, torulose, the seeds solitary or in pairs at the (2 to 4) nodes and comose at the summit. — In the Sierra Madre, south of Saltillo (805); 987 Coulter.

PLUMIERA ——? A fruiting specimen of what is cultivated at Monterey as the "Cow Tree." Follicles 6 to 9 inches long by an inch wide or more; leaves narrow.

MACROSIPHONIA BERLANDIERI, Gray. In the mountains on the west side of Saltillo (807), as well as at Monclova and in the mountains north of it. Flowers cream-white and fragrant; popularly known as "Flor de San Juan."

MACROSIPHONIA HYPOLEUCA, Muell. At Guanajuato (Dugès), with the same popular name; 574 Parry & Palmer.

PHILIBERTIA CYNANCHOIDES, Benth. & Hook. At Laredo, on the Rio Grande (821).

PHILIBERTIA LINEARIS, Benth. & Hook., var. HETEROPHYLLA, Gray. At Parras, Coahuila (822).

PHILIBERTIA ELEGANS, Benth. & Hook. In the San Miguelito Mountains, San Luis Potosi (649 Schaffner), and at Guanajuato (Dugès); 589 Parry & Palmer.

ASCLEPIODORA DECUMBENS, Gray. At Sutherland Springs, Texas (817), and in the Sierra Madre, south of Saltillo (818). The Mexican specimen is referred by Fournier (Ann. Sci. Nat. 6. 14. 369) to *A. asperula*, Fourn. (*Acerates asperula*, Decaisne), which it may be, though it seems to differ in no respect from ordinary *A. decumbens*. *A. viridis* is not certainly known from Mexico, as Andrieux' and Bourgeau's specimens so named by Hemsley are referred by Fournier to *Asclepias auriculata*.

ASCLEPIODORA CIRCINALIS, Fournier, l. c. 369. (*Acerates circinalis*, Decaisne.) At Saltillo (815); in fruit only and in every way resembling *Asclepias brachystephana*, Engelm., but in the glabrous leaves and the umbels sessile in the upper axils. Fournier describes the follicles as 3 inches long, but in these specimens they do not exceed half of that, as in *A. brachystephana*.

ACERATES VIRIDIFLORA, Ell. Sparingly collected at Sutherland Springs, Texas, and in the Caracol Mountains, Coahuila.

ASCLEPIAS VERTICILLATA, Linn. At Parras, Coahuila (809, in part), and at San Luis Potosi (Schaffner); 584 Parry & Palmer. — Also var. SUBVERTICILLATA, Gray, at Guadalupe (810) and Sutherland Springs (2093), and at Parras with the typical form (809).

ASCLEPIAS LINARIA, Cav. At Lerios, Coahuila (811), and at Guanajuato (Dugès), where it is known as "Venenillo"; 585 Parry & Palmer.

ASCLEPIAS PERENNIS, Walter, var. PARVULA, Gray. At Sutherland Springs, Texas (2092), and in the Caracol Mountains, Coahuila (812). The Mexican specimens are referred by both Hemsley and Fournier to *A. nivea*, Linn., which has greener flowers, with longer hoods, and the horns not exserted.

ASCLEPIAS BRACHYSTEPHANA, Engelm. At Parras (813), and in the mountains east of Saltillo (814); 576 Parry & Palmer.

ASCLEPIAS GLAUCESCENS, HBK. (*A. elata*, Benth.) In the Sierra Madre, south of Saltillo (816); 579 Parry & Palmer.

ASCLEPIAS LONGICORNU, Benth. At Sutherland Springs, Texas (819, 2094); 587 Parry & Palmer.

ASCLEPIAS SETOSA, Benth. At Guanajuato (Dugès); popularly known as "Taraumara."

Metastelma Californicum, Benth. In the Caracol Mountains, Coahuila (828), and near San Luis Potosi (625 Schaffner, in part).

Metastelma Palmeri. Twining, glabrous or with a pilose line upon the stem above: leaves linear-lanceolate, acuminate, cuneate or sometimes rounded at base, shortly petiolate, ½ to 1 inch long: corymbs nearly sessile, 3–10-flowered, glabrous; pedicels a line long or less: calyx-lobes acutish; corolla thick, white or brownish externally, over a line long, open-campanulate, the oblong lobes acutish, pubescent within: crown of five distinct thickish acuminate-subulate scales, exceeding the flat stigma: follicles 1½ inches long. — At Laredo on the Rio Grande (824), and about San Luis Potosi (625 Schaffner, in part); collected also at Chiapas (664 Ghiesbreght), and in the valley of Mexico (627 Bourgeau).

Vincetoxicum Mexicanum. Stems herbaceous, slender, twining, 2 or 3 feet long, with a hairy line on one side: leaves linear to linear-lanceolate, acuminate, cuneate or slightly rounded at base, ½ to 1½ inches long, glabrous or sparingly pubescent, or puberulent beneath: corymbs somewhat pubescent, sessile or nearly so, 1–10-flowered; pedicels a line long or less: calyx-lobes obtusish; corolla white, ⅔ of a line long, open-campanulate, the rather broad lobes obtusish, glabrous: crown of five thin ovate-oblong obtusish scales, distinct or nearly so, somewhat exceeding the flat stigma: follicles 2 to 2½ inches long. — In the Sierra Madre, south of Saltillo (823), and near San Luis Potosi (652 Schaffner, in part); 575 Parry & Palmer; Orizaba (342 and 984 Botteri). This may be the same as *Metastelma angustifolium*, Turcz.

Roulinia unifaria, Engelm. At San Antonio, Texas (827).

Roulinia Palmeri. With the habit, foliage, pubescence and fruit of the last: peduncle shorter than the petiole, the corymbose raceme 3–6-flowered; pedicels unequal, 3 to 6 lines long: flowers larger, the linear calyx-lobes 1½ to 2 lines long; corolla 2 lines long, with a short tube, the greenish lobes whiter and somewhat thickened above: coronal scales united at base, quadrate, about equalling the stigma, obtusely 3-lobed at the summit, or the middle lobe longer and triangular-cuspidate. — In the mountains north of Monclova, Coahuila (829). Referred by Hemsley to the last, from which it differs chiefly in the characters of the flowers.

Gonolobus parviflorus, Gray. At Laredo on the Rio Grande (820).

Gonolobus reticulatus, Engelm. At San Antonio, Texas (825), and at Soledad, Coahuila (826).

GONOLOBUS PILOSUS, Benth. Near Morales, San Luis Potosi (650 Schaffner), and at Guanajuato (Dugès), where it is called "Flor del muerto negra"; 591 Parry & Palmer.

GONOLOBUS SCHAFFNERI, Gray. In the mountains near San Luis Potosi (651 Schaffner).

GONOLOBUS ERIANTHUS, Decaisne. At Guanajuato (Dugès); "Flor del muerto verde."

GONOLOBUS (?), sp. Somewhat woody, pubescent, the ovate acute leaves (1 or 2 inches long) cuneate to truncate at base or subcordate; in fruit only. In the mountains north of Monclova (830).

MITREOLA PETIOLATA, Torr. & Gray. At Sutherland Springs, Texas (1031).

POLYPREMUM PROCUMBENS, Linn. At Sutherland Springs, Texas (78), and near Morales, San Luis Potosi (117 Schaffner); 59 Parry & Palmer.

BUDDLEIA MARRUBIIFOLIA, Benth. At Parras (834), in the mountains west of Saltillo (1020) and north of Monclova (1019). "Flowers orange."

BUDDLEIA VERTICILLATA, HBK. (*B. sessiliflora*, HBK.) At Monterey, Nuevo Leon (835, 965), in the mountains near San Luis Potosi (632 Schaffner), and at Guanajuato (Dugès, who gives the popular name "Tepozan"); 594 Parry & Palmer. Described by Palmer as a large loosely branching bush, with greenish yellow flowers and a strong rather offensive odor. The larger leaves are frequently toothed.

BUDDLEIA SCORDIOIDES, HBK. In the high mountains at Lerios (836), at Parras (837), and in the mountains near San Luis Potosi (633 Schaffner, in part, under the name "Escobilla"); 592 and 595 Parry & Palmer. Also var. CAPITATA, with the whorls all contiguous and crowded at the ends of the branches; with the usual form (633 Schaffner, in part, as "Yerba de las escolas").

BUDDLEIA PERFOLIATA, HBK. In the mountains near San Luis Potosi (634 Schaffner); 593 and 596 Parry & Palmer.

BUDDLEIA HUMBOLDTIANA, Roem. & Schult. Variable and doubtless including several nominal species. At Saltillo (869), and at San Luis Potosi (635 Schaffner); 593½ and 725 Parry & Palmer. Schaffner's specimen, with very large leaves, accords with the description of *B. macrophylla*, Kunth. *B. Americana*, Linn. (594½ Parry & Palmer), may be distinguished by the leaves decurrent nearly to the base of the petiole, and by the longer and more simple branchlets of the panicle.

ERYTHRÆA CALYCOSA, Buckl. At Parras, Coahuila (838). With rather small flowers; the same as collected by Gregg between Mapimi and Guajuguilla.

ERYTHRÆA ——? At Guanajuato (Dugès). With the compact cymes of *E. tricantha*, but with very much smaller seeds. Probably an undescribed species, but the specimens are incomplete.

EUSTOMA EXALTATUM, Griseb. At Laredo, on the Rio Grande (840), and at Parras, Coahuila (841).

GENTIANA LANCEOLATA, Griseb. At Guanajuato (Dugès).

GENTIANA SPATHACEA, HBK. At Guanajuato (Dugès), known as "Yelera"; 599 Parry & Palmer.

HALENIA ROTHROCKII, Gray. In the Sierra Madre, south of Saltillo (839).

PHLOX DRUMMONDII, Hook. Near San Antonio, Texas (844).

GILIA RIGIDULA, Benth. At Parras, Coahuila (843). Also a smaller-flowered form, glandular-pubescent, with the lobes of the leaves all very narrow; at Sutherland Springs, Texas (1185), and at Soledad (845); 605 Parry & Palmer, nearly the same. — Var. ACEROSA, Gray. At Saltillo (842).

GILIA INCISA, Benth. At San Antonio, Texas (846), in the Caracol Mountains, Coahuila (2107), at Monterey (847) and at Guajuco, Nuevo Leon; 601 Parry & Palmer.

GILIA AGGREGATA, Spreng. In the high mountains at Lerios.

LŒSELIA CÆRULEA, Don. At Parras, Coahuila (2041), at Monterey, Nuevo Leon (848), and near San Luis Potosi (639 Schaffner); 603 Parry & Palmer.

LŒSELIA COCCINEA, DC. In the mountains near San Luis Potosi (638 Schaffner); 604 Parry & Palmer.

LŒSELIA GLANDULOSA, Don. At Guanajuato (Dugès); the typical form.

LŒSELIA GREGGII. Erect, branching below, pubescent: leaves opposite, the upper sometimes alternate, lanceolate, sessile or nearly so, ½ to 1 inch long, acute, serrate, the teeth awned: floral bracts broadly ovate or the inner lanceolate, mostly scarious, coarsely serrate and the teeth setosely tipped, not ciliate, nearly glabrous: calyx-lobes lanceolate, acuminate, lacerate; corolla 6 lines long, pink with white centre. — At Saltillo, Coahuila (1063), and also collected by Dr. Gregg (360). Allied to *L. ciliata*, Linn., which appears to include *L. involucrata*, Don (702 Parry & Palmer).

PHACELIA CONGESTA, Hook. At Monterey, Nuevo Leon (2028), and a very hispid form from Corpus Christi, Texas (849).

PHACELIA GLANDULOSA, Nutt., var. NEO-MEXICANA, Gray. In the mountains east of Saltillo (850).

PHACELIA INTEGRIFOLIA, Torr. At San Lorenzo de Laguna, Coahuila (851).

WIGANDIA KUNTHII, Choisy. At Guanajuato (Dugès). Known as "Ortiga grande."

NAMA* STENOCARPUM, Gray. In Coahuila, very common (853, 857). The anomalous cohesion of calyx-tube with ovary and capsule in this species (of which traces may be detected in some other species), which long escaped notice, I have referred to in the account of this genus contributed to the Botany of the Biologia Centrali-Americana, page 361. Our attention was first called to it by Dr. Vasey. The character "capsula inferne cum calyce longius adnata" in the work referred to, which belongs to this species, is accidentally appended to *N. stenophyllum.*

NAMA HISPIDUM, Gray. Different forms, from Sutherland Springs, Texas (2108), Monclova, Coahuila (860), and Monterey, Nuevo Leon (854).

NAMA DICHOTOMUM, Choisy, var. ANGUSTIFOLIUM, Gray. In the Sierra Madre, south of Saltillo (855), and in the San Rafael Mountains, San Luis Potosi (613 Schaffner). 610 Parry & Palmer is the typical form.

NAMA PALMERI, Gray in Hemsl. Bot. Biol. Centr.-Amer. 2. 361. At Soledad, Coahuila (856), and at San Luis Potosi, a more canescent form (77 Schaffner); 615½ Parry & Palmer.

NAMA UNDULATUM, HBK. At Monclova, Coahuila (858); 607 and 608 Parry & Palmer.

NAMA COULTERI, Gray. At San Lorenzo de Laguna, Coahuila (859). The sepals are scarcely dilated upward; but this appears to be the plant of Coulter, and also of Gregg. I had taken Palmer's plant for a form of the polymorphous *N. hispidum.*

NAMA STENOPHYLLUM, Gray, l. c. [Exclude the last phrase of the specific character, which was appended by mistake in transcribing. As the context shows (see line 5 of the same page), this belongs to *N. stenocarpum.*] At San Lorenzo de Laguna, Coahuila (862), clearly frutescent and evidently a denizen of saline soil. Dr. Havard has collected the same on the banks of Delaware Creek, near the Rio Grande, in Texas. Also a more hirsute and herbaceous form, from the same region (861).

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* The determinations and notes under this genus are contributed by DR. GRAY.

NAMA SERPYLLOIDES, Gray, l. c., 363. At Monclova (982).

NAMA RUPICOLA, Pavon. At Soledad, Coahuila (2023); 612 Parry & Palmer, in part. — Var. ROTUNDIFOLIUM, Gray, l. c., 363. At Monclova, Coahuila (983), and a very soft-villous rounder-leaved form from Monterey, Nuevo Leon (984).

NAMA SUBPETIOLARE, Gray, l. c., 365. Near Monterey, Nuevo Leon (985).

NAMA JAMAICENSE, Linn. At Monterey (986).

NAMA ORIGANIFOLIUM, HBK. The specimens which best accord with Kunth's figure are from San Luis Potosi (732 Schaffner). Some of 612 Parry & Palmer are the same, while others appear to belong to *N. rupicola.*

NAMA SCHAFFNERI, Gray, l. c., 361. Near Morales, San Luis Potosi (194 Schaffner); 609 Parry & Palmer.

CORDIA GREGGII, Torr. At San Lorenzo de Laguna, Coahuila (876).

CORDIA BOISSIERI, DC. At Monterey, Nuevo Leon (877), where it is popularly known as "Nacaguista" and a decoction of the bark is much used for coughs and colds; 1126 Parry & Palmer.

CORDIA PODOCEPHALA, Torr. At Soledad, Coahuila (1024).

EHRETIA ELLIPTICA, DC. (*E. ciliata* and *E. exasperata,* Miers.) At Corpus Christi, Texas (870), in fruit, and at Monterey, Nuevo Leon (871), in flower; 591½ Parry & Palmer. Growing to a height of 20 or 30 feet, and retaining its leaves and abundant fruit most of the year; the pale yellow sweetish berries edible; flowers cream-white, very fragrant. The Mexican specimens have been referred to *E. ciliata,* Miers, which was founded upon a Texan specimen (665 Lindheimer) and cannot be distinguished from *E. elliptica.*

COLDENIA CANESCENS, DC. At Parras (873) and Monclova, Coahuila (874, in part), at Monterey, Nuevo Leon (1018), and in the San Miguelito Mountains, San Luis Potosi (631 Schaffner); 615 Parry & Palmer. Flowers described as light blue, becoming pink.

COLDENIA HISPIDISSIMA, Gray. At Monclova, Coahuila (898). "Flowers rose-color."

COLDENIA (EDDYA) MEXICANA. Perennial, woody at base, prostrate, more or less setosely hispid and tomentose: leaves ovate to broadly lanceolate, more or less abruptly attenuate into a slender petiole, veinless: flowers sessile, clustered; sepals narrowly linear; corolla 3 lines long, rose-color: nutlets (only two usually maturing) less finely and closely granulated than in the last, scarcely ½ line long. — In the mountains east of Saltillo (872), and at Monclova, Coahuila

(874, in part); 616½ Parry & Palmer. Much resembling *C. canescens*, but with more ovate leaves, and with the fruit and the more unequally inserted stamens of the section *Eddya*. The embryo is straight and the cotyledons entire.

COLDENIA TOMENTOSA. Resembling the last, but of closer habit and more densely leafy, the thicker ovate-lanceolate leaves densely tomentose beneath, as well as setosely hispid, more strongly revolute and mostly with shorter petioles: flowers somewhat larger, "purple" or "magenta," with longer filaments and larger anthers: nutlets decidedly larger (⅔ of a line long) and more coarsely granulated. — In the Sierra Madre, south of Saltillo (864).

COLDENIA GREGGII, Gray. At San Lorenzo de Laguna, Coahuila (865). "Flowers rose-color."

TOURNEFORTIA CAPITATA, Mart. & Gal. At Guanajuato (Dugès); 613 Parry & Palmer.

TOURNEFORTIA MONCLOVANA. Perennial, stout, herbaceous, a foot high, tomentosely pubescent throughout: leaves ovate to oblong-lanceolate, acute, abruptly cuneate at base, 2 to 4 inches long, on stout petioles: spikes in pairs or threes, on peduncles nearly equalling the leaves, ebracteolate: calyx-lobes narrowly linear, 1½ lines long; corolla glabrous, 3 or 4 lines long, the limb as long as the tube, and throat naked: anthers sessile on the middle of the tube, acute: stigma conical, sessile: fruit subglobose, pubescent, 1½ lines in diameter. — In the mountains northeast of Monclova, Coahuila (887). Resembling *T. hirsutissima*, but with more simple inflorescence, glabrous corolla, etc.

HELIOTROPIUM ANGUSTIFOLIUM, Torr. In the Caracol Mountains (879), at Soledad (880), and Juraz, in Coahuila (881), and at Monterey, Nuevo Leon (405, 878). Flowers cream-color.

HELIOTROPIUM CONFERTIFOLIUM, Torr. At Laredo, on the Rio Grande (875), the typical form; 616 Parry & Palmer. This is probably the same as *H. rupestre*, Mart. & Gal., which is an older name. Also a less silky variety, more diffuse and with the leaves less crowded, from Monclova (863) and Soledad, Coahuila (890). This is the *H. limbatum* of the Botany of the Mexican Boundary, scarcely differing from *H. limbatum*, Benth., but in the more leafy and scarcely at all scorpioid inflorescence. Flowers white.

HELIOTROPIUM INUNDATUM, Swartz. At San Lorenzo de Laguna, Coahuila (882), and a low decumbent form in the San Miguelito Mountains of San Luis Potosi (726 Schaffner); 619 Parry & Palmer. Also a variety, more canescent and with larger and more hispid fruit in closer spikes, from Monterey (885). 522 Coulter and specimens collected by Palmer in 1869 on the Yaqui River, Arizona, are nearly the same. Flowers yellow or yellowish.

HELIOTROPIUM GLABRIUSCULUM, Torr. At Laredo on the Rio Grande (884), and in the mountains west of Saltillo, Coahuila (883). Flowers cream-white.

HELIOTROPIUM PARVIFLORUM, Linn. At Laredo on the Rio Grande (886) and in the region west of San Antonio, Texas, and at Monclova, Coahuila (1021); 617 Parry & Palmer.

HELIOTROPIUM GREGGII, Torr. At San Lorenzo de Laguna, Coahuila (888).

HELIOTROPIUM CONVOLVULACEUM, Gray. In the region west of San Antonio, Texas (889).

HELIOTROPIUM (EUHELIOTROPIUM) PALMERI, Gray in herb. Perennial, herbaceous, branching from the base, the slender stems ascending, strigose-pubescent throughout, a span high: leaves linear, or linear-oblanceolate on the main stem, nearly sessile, acute or obtusish, 6 to 10 lines long, the margin somewhat revolute: spikes mostly lateral and simple, ebracteolate, becoming one or two inches long in fruit, rather few-flowered: calyx-lobes linear, a line long or less; corolla white, 3 lines long, with a broad spreading limb: nutlets subglobose, pubescent. — At Soledad, Coahuila (891, 892); very common.

HELIOTROPIUM CURASSAVICUM, Linn. About San Luis Potosi (724 Schaffner).

OMPHALODES ALIENA, Gray; Hemsley, Bot. Biol. Centr.-Amer. 2. 377. At Monterey, Nuevo Leon (893).

OMPHALODES CARDIOPHYLLA, Gray; Hemsley, l. c. At Saltillo, Coahuila (894). The relations of these species are hardly clear. They seem to belong to *Paracaryum* rather than to *Omphalodes*, if these genera are to be retained as characterized by Bentham & Hooker, the nutlets being attached nearly their whole length, from just above the base to the apex, to the erect-pyramidal gynobase. The thin-membranous character of the flattened nutlets, as well as the habit, separates them from *Echinospermum*.

ERITRICHIUM FULVOCANESCENS, Gray. In the Sierra Madre, south of Saltillo (895).

ERITRICHIUM HISPIDUM, Buckl. At Lerios in the high mountains east of Saltillo (896, 2046), and in the San Rafael Mountains, San Luis Potosi (731 Schaffner); 623 Parry & Palmer.

ANTIPHYTUM FLORIBUNDUM, Gray. In the San Miguelito Mountains, San Luis Potosi (730 Schaffner).

ANTIPHYTUM PARRYI. Perennial (?), low (2 to 4 inches high), branching from the base, stems ascending, canescent with a somewhat silky and substrigose pubescence: leaves linear-oblanceolate, 2 to 4 lines long: flowers nearly sessile, axillary: calyx-lobes linear, 2 lines long: nutlets granulate, the sessile triangular-ovate scar with a narrow slightly raised margin and minute central perforation. — 618 Parry & Palmer (with some *Heliotropium confertifolium*), collected by Dr. Parry, in August, 1878, between San Luis Potosi and San Antonio.

LITHOSPERMUM SPATHULATUM, Mart. & Gal. In the Sierra Madre, south of Saltillo (899); a low hispid form.

LITHOSPERMUM MATAMORENSE, DC. At Guajuco (901) and Monterey, Nuevo Leon (902). Referred by Hemsley to *Eritrichium.*

LITHOSPERMUM ANGUSTIFOLIUM, Michx. At Lerios, in the mountains east of Saltillo (900), the small-flowered form, and with nutlets not punctate. Also a variety with laxer habit, broader leaves, and larger flowers; in the Caracol Mountains (897), and at Soledad, Coahuila.

LITHOSPERMUM STRICTUM, Lehm. Near San Miguelito, San Luis Potosi (728 Schaffner); 620 and 622 Parry & Palmer.

LITHOSPERMUM DISTICHUM, Ort. In the San Miguelito Mountains (729 Schaffner); 621 Parry & Palmer.

LITHOSPERMUM PALMERI. Perennial, herbaceous, tall and erect (2 feet high), pubescent with mostly very short strigose hairs: leaves sessile, ovate-oblong, acute or short-acuminate, 1 to 2 inches long: flowers axillary, on pedicels 3 to 6 lines long: calyx villous below, the linear acuminate lobes 6 to 8 lines long; corolla cream-yellow, nearly an inch long, tomentose, cylindrical, contracted at the naked throat, with small rounded spreading lobes: style as long as the corolla: nutlets not punctate, nor much contracted above the base. — In the Sierra Madre, south of Saltillo, Coahuila (903). With the habit of an *Onosmodium.*

IPOMŒA CARDIOPHYLLA, Gray. At Soledad, Coahuila (904). The peduncles mostly several-flowered, longer than the petioles.

IPOMŒA MEXICANA, Gray. At Soledad (905).

IPOMŒA LINDHEIMERI, Gray. At Soledad (906).

IPOMŒA COMMUTATA, Roem. & Schult. At Soledad (907).

IPOMŒA SINUATA, Ort. At Uvalde, Texas (908).

IPOMŒA TRIFIDA, Don, var. TORREYANA, Gray. At Bluffton, Texas (909).

IPOMŒA MURICATA, Cav. In the Sierra Madre, south of Saltillo (910).

Ipomœa costellata, Torr. In the mountains northeast of Monclova, Coahuila (2095).

Ipomœa stans, Cav. At San Lorenzo de Laguna, Coahuila, at San Luis Potosi (1050 Schaffner), and at Guanajuato (Dugès); 627 Parry & Palmer. Dugès gives the popular name "Espantolobos."

Ipomœa heterophylla, Ort. (?) Near Morales, San Luis Potosi (619 Schaffner). Resembling *I. Lindheimeri*, but with smaller flowers; the same as 389 Gregg.

Ipomœa coccinea, Linn., var. hederifolia, Gray. At San Luis Potosi (622 Schaffner); 625 Parry & Palmer.

Ipomœa versicolor, Meissn. At San Luis Potosi (111 Schaffner), and Guanajuato (Dugès), where it is known as "Palmira."

Ipomœa Llaveana, Meissn. At Guanajuato (Dugès); "Trompetilla."

Ipomœa Schaffneri. Annual, twining, 3 to 5 feet high, sparingly pubescent with short strigose hairs: leaves thick, round-cordate, with rounded or slightly angled approximate basal auricles, acute, coarsely sinuate-toothed, 1 or 2 inches in diameter, exceeding the petioles: pedicels shorter than the leaves, 1-flowered: calyx-lobes hispid, oblong-ovate, acute, 4 lines long; corolla 2 inches long, rose-color and white, funnelform with a rather broad tube, the stamens and style two-thirds as long: capsule depressed-globose to ovate, 4 lines long, 3-celled. — In sandy places about San Luis Potosi (621 Schaffner); peculiar in its round-cordate sinuately toothed leaves.

Ipomœa ——? In sandy places about San Luis Potosi (620 Schaffner); not identified. A slender twining annual, 2 feet high, glabrous or slightly puberulent: leaves 9 to 18 lines long, broad-cordate to narrowly lanceolate, acuminate, often obscurely sinuate, the short basal lobes rounded or angled; peduncles about equalling the petioles and shorter than the leaves, 1–2-flowered: sepals lanceolate becoming oblong-ovate and obtuse or acute, 2 lines long; corolla 9 lines long, narrowly funnelform, purple above: capsule broadly ovate, 3 lines long, 2-celled.

Convolvulus incanus, Vahl. At Monterey, Nuevo Leon (911), and about San Luis Potosi (618 Schaffner); 629 Parry & Palmer.

Evolvulus discolor, Benth. At Lerios in the high mountains east of Saltillo, Coahuila (912). Scarcely more than a very villous form of the next.

Evolvulus sericeus, Swartz. At Sutherland Springs, Texas (913, 914), and near San Luis Potosi (615^b Schaffner); 628½ Parry & Palmer.

EVOLVULUS ALSINOIDES, Linn. At Monclova, Coahuila (915), at Monterey, Nuevo Leon (2096), at San Luis Potosi (615 Schaffner), and at Guanajuato (Dugès); 628 Parry & Palmer.

DICHONDRA REPENS, Forst. At Guanajuato (Dugès).

DICHONDRA ARGENTEA, Humb. & Bonpl. About San Luis Potosi (617 Schaffner), and at Guanajuato (Dugès); 624 Parry & Palmer. The popular name is "Oreja de raton."

CRESSA CRETICA, Linn. At San Lorenzo de Laguna, Coahuila.

CUSCUTA UMBELLATA, HBK. At Laredo on the Rio Grande (916).

CUSCUTA SQUAMATA, Engelm. At San Lorenzo de Laguna, Coahuila (917, 2098).

CUSCUTA ARVENSIS, Beyr. At Parras, Coahuila (919). Also var. VERRUCOSA, Engelm., at San Luis Potosi (780 Schaffner).

CUSCUTA POTOSINA, Schaffner Ms. Stems capillary: the flowers minute (scarcely a line long), short-pedicelled in small rather loose clusters: calyx-lobes triangular, acute, scarcely equalling the deeply campanulate corolla-tube, which is rather longer than its erect ovate acute somewhat inflexed and at last connivent lobes: stamens short, the subglobose anthers nearly as long as the filaments; scales broad, deeply fringed, slightly exceeding the tube: capillary styles nearly as long as the depressed ovary: capsule covered by the marcescent corolla, extremely thin, easily tearing off from its base but not circumscissile, 1-seeded. — One of the smallest-flowered species, closely allied to *C. arvensis*, from which the very fragile 1-seeded capsule, covered by the hood-like corolla, principally distinguishes it. (*Dr. G. Engelmann.*) — Near San Luis Potosi (779 Schaffner); growing on some labiate, probably a *Scutellaria.**

CUSCUTA DECORA, Chois. At Bluffton, Texas (2097).

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* Dr. Engelmann furnishes the following description of another new species, which was distributed in the previous Parry & Palmer collection: —

C. MITRÆFORMIS, Engelm. Stems thick: flowers short-pedicelled, crowded in large glomerules: calyx-lobes orbicular, unequal, the outer carinate, fully as long as the short-campanulate corolla-tube; lobes of the corolla as long as the tube, broadly oval, rounded, at last spreading or reflexed: subulate filaments as long as the linear-oblong anthers; scales very broad, deeply fringed, exsert, incurved: ovary with very short subulate styles: capsule large, exsert, 2-horned with the broad spreading conical styles, regularly circumscissile. — Between San Luis Potosi and Tampico, in May; Dr. E. Palmer. Flowers 3 lines and capsule 4 lines long; clusters in fruit 10 to 12 lines thick. Nearly allied to *C. Xalapensis*, but distinguished by its much larger flowers and fruit, and by its short thick almost conical styles.

CUSCUTA TINCTORIA, Mart. In the Caracol Mountains, Coahuila, on *Serjania* (918), and in the mountains near San Luis Potosi, on *Schinus Molle* (781 Schaffner); 631 Parry & Palmer (referred to *C. Xalapensis*), also on *Schinus*. The popular name, according to Dr. Schaffner, is "Zacatlas-culi," — evidently the "Zaca-tlascalli" of Karwinski.

CUSCUTA ODONTOLEPIS, Engelm. At Guanajuato (Dugès). Dr. Engelmann recognizes this as referable to *C. odontolepis*, though with wider and shorter calyx than in the original specimens, the lobes acuminate and often reflexed, the scales much larger, ovate and deeply fimbriate, and the style shorter.

SOLANUM TRIQUETRUM, Cav. At San Antonio, Texas (929), and at Saltillo (930); 633½ Parry & Palmer.

SOLANUM TORREYI, Gray. At San Antonio (2102), Uvalde (932), and Bluffton, Texas (933).

SOLANUM NIGRUM, Linn. In various forms, at Lerios and in the Caracol Mountains, Coahuila, at Monterey, Nuevo Leon (934), and at Guanajuato (Dugès); 634 Parry & Palmer. Also with somewhat angled and spinulose branches, the *S. pterocaulon* of Dunal, in sandy places near San Luis Potosi (692 Schaffner), and the var. VILLOSUM, Mill., in the mountains about San Luis Potosi (691 Schaffner).

SOLANUM ELÆAGNIFOLIUM, Cav. At Laredo, on the Rio Grande (2101), at San Lorenzo de Laguna, Coahuila (935, 936), and at San Luis Potosi (695 Schaffner); 636 Parry & Palmer.

SOLANUM TUBEROSUM, Linn. In the Sierra Madre, south of Saltillo (937, 938), and in the mountains near San Luis Potosi (693, 694 Schaffner); 632, 633 Parry & Palmer. Schaffner gives the popular name "Peyrilla del monte."

SOLANUM HETERODOXUM, Dun. In the mountains northeast of Monclova (939), and at Parras, Coahuila (940). Also with smaller flowers and light-colored seeds, at San Luis Potosi (696 Schaffner); 634½ Parry & Palmer. The seeds ordinarily are nearly black.

SOLANUM ROSTRATUM, Dun. At San Antonio, Texas (941), at Saltillo (942), and at Guanajuato (Dugès). A form with somewhat less pubescence occurs near San Luis Potosi (697 Schaffner); 635 Parry & Palmer, referred to *S. cornutum*, Lam., of which there are no specimens in Herb. Gray, — unless, as is probable, *S. rostratum* itself is to be considered only as the more pubescent form of it. Known, according to Dugès, as "Mala muger."

SOLANUM CERVANTESII, Lag. At San Luis Potosi (690 Schaffner); 638 Parry & Palmer.

SOLANUM TORVUM, Swartz. At Guanajuato (Dugès); 639½ Parry & Palmer. 637 Parry & Palmer is also referred to this species.

PHYSALIS LOBATA, Torr. At Uvalde, Texas (944), and in the mountains west of Saltillo (943).

PHYSALIS VISCOSA, Linn., var. SPATHULÆFOLIA, Gray. At Lamar on Copano Bay, Texas, near salt water (945). Fruit greenish yellow, with a very strong overripe-apple odor.

PHYSALIS ÆQUATA, Jacq. f. At San Lorenzo de Laguna, Coahuila (946); 640 Parry & Palmer.

PHYSALIS ANGULATA, Linn. At Sutherland Springs, Texas (947).

PHYSALIS MOLLIS, Nutt. On Corpus Christi Bay, Texas (2103). — Var. CINERASCENS, Gray, at Parras, Coahuila (949), at Monterey, Nuevo Leon (948), at San Luis Potosi (700 Schaffner), and at Guanajuato (Dugès), where it is known as "Taltomate"; 641 and 648 Parry & Palmer. 112 Bourgeau, referred to *P. chenopodiifolia*, Lam., is *P. mollis*.

PHYSALIS PUBESCENS, Linn. In the mountains northeast of Monclova (2104), and near Morales, San Luis Potosi (701 Schaffner, in part); 645 Parry & Palmer.

PHYSALIS PHILADELPHICA, Lam. Near Morales, San Luis Potosi (701 Schaffner, in part). 871 Bourgeau is the same.

PHYSALIS FENDLERI, Gray. In the mountains near San Luis Potosi (698 Schaffner); 642 Parry & Palmer.

PHYSALIS ——? A low branching perennial, glandular-pubescent, with slender somewhat flexuous stems and small ovate to ovate-oblong entire or sinuate-toothed leaves (3 to 12 lines long), and yellow flowers (9 lines broad) on pedicels shorter than the fruiting calyx. — In the San Miguelito Mountains, San Luis Potosi (699 Schaffner).

CHAMÆSARACHA CORONOPUS, Gray. Various forms of this very variable species, including in it *C. sordida*, Gray. With lanceolate coarsely toothed leaves, large flowers, and long solitary pedicels — with mostly short pubescence, at San Antonio, at Sutherland Springs, and at Laredo, Texas (920), and in the mountains west of Saltillo (926) — and more villous, at Monterey, Nuevo Leon (921, 922); very floccose-villous, with similar leaves, but small flowers and fascicled pedicels, in the mountains northeast of Monclova (924); a common form, pubescent or sparingly floccose-villous, with narrow pinnatifid leaves and small flowers, at Parras (2099), at San Lorenzo de Laguna (927, 928, and 2100 with "pure white" flowers), and at San Luis Potosi (703 Schaffner); with ovate leaves, abruptly cuneate at base and crenately toothed, and fruit large, at Parras (923), and with similar but smaller and sinuately-toothed leaves, and with smaller flowers and fruit, at San Lorenzo de Laguna (925); 653 Parry & Palmer. In the multiplicity of forms it seems impossible to distinguish two species, unless it be arbitrarily upon some single character.

SARACHA UMBELLATA, Don. (*S. glabrata*, Miers.) Near San Luis Potosi (702 Schaffner); 651 Parry & Palmer; also 347 Bourgeau, referred to *S. Jaltomata.* Roth originally described the species (in 1800) from cultivated plants, without giving their source, but Jacquin in 1804 refers the species positively to Mexico.

CAPSICUM BACCATUM, Linn. At Uvalde (931), and at Sutherland Springs, Texas; 1135 Parry & Palmer.

CACABUS MEXICANUS. Viscidly pubescent throughout, rather stout: leaves broadly ovate and mostly cordate, or the upper ovate-oblong, coarsely sinuate-toothed or nearly entire, obtuse or acute, 2 inches long and exceeding the petioles, the upper and secondary ones smaller: flowers solitary; calyx broadly tubular-campanulate, 6 (becoming 15) lines long, with acuminate teeth; corolla purplish, 15 lines long, broadly funnelform, nearly glabrous without, densely tomentose toward the base within, the limb nearly entire: berry subglobose, 6 lines in diameter, loosely enclosed in the inflated 10-carinate calyx. — In the San Miguelito Mountains, San Luis Potosi (704 Schaffner). Near *C. prostratus*, Bernh.

NECTOUXIA FORMOSA, HBK. At Lerios, Coahuila (958); 652 Parry & Palmer.

LYCIUM BRACHYANTHUM, Gray in Hemsl. Bot. Biol. Centr.-Amer. 2. 426. At Laredo, on the Rio Grande (963), in the mountains west of Saltillo (866), and at Soledad, Coahuila (867, 868); 723 Parry & Palmer. A small loosely branched bush, the angular branches pubescent or glabrate, with obovate to oblanceolate or spatulate short-pubescent fascicled leaves (2 to 8 lines long by 1 or 2 wide), and nearly sessile flowers: calyx pubescent, with very short and broad lobes, equalling the broad tube of the cream-white corolla, which is densely woolly within and about 2 lines long: mature fruit 3 lines in diameter.

LYCIUM BERLANDIERI, Dun. At Guadalupe, Texas (950), and westward to Laredo (951, 952), at Saltillo (957) and in the mountains west of that place (954, 956), and at San Luis Potosi (1059 Schaffner); 654, 654½, and 656½ Parry & Palmer. Apparently all forms of the same species, though the Mexican specimens have mostly shorter pedicels, the fruit is sometimes smaller, and the corolla varies to some extent.

LYCIUM CAROLINIANUM, Walt. On Corpus Christi Bay, Texas (953), trailing on the ground and rooting at the joints.

LYCIUM BARBINODUM, Miers, var. (?) In the mountains west of Saltillo (955). With shorter and more spreading corolla than in the forms of *L. Berlandieri*, but with smaller leaves and much shorter pedicels than in typical *L. barbinodum*. Flowers described as lavender-color or violet.

LYCIUM SCHAFFNERI, Gray. At San Luis Potosi (Schaffner); 655 Parry & Palmer.

DATURA QUERCIFOLIA, HBK. At Parras, Coahuila (959), and at San Luis Potosi (705, 706 Schaffner); 658 Parry & Palmer.

DATURA METELOIDES, DC. At San Lorenzo de Laguna, Coahuila (960), in the San Miguelito Mountains, San Luis Potosi (707 Schaffner), and at Guanajuato (Dugès), where it is known as "Toloachi."

HYOSCYAMUS ALBUS, Linn. At San Lorenzo de Laguna, in cultivation (964), and naturalized about San Luis Potosi (708 Schaffner), where it was introduced by the French.

CESTRUM MULTINERVIUM, Dun. At San Antonio, Texas (808).

CESTRUM LAXUM, Benth. At Guanajuato (Dugès); popularly known as "Huele de noche de la Sierra."

CESTRUM LANATUM, Mart. & Gal. At Guanajuato (Dugès); "Ahuacatillo."

NICOTIANA NUDICAULIS. Viscid-pubescent, 1 to 2 feet high, the stem and naked branches bearing short paniculate or simple racemes: leaves mostly at the base, entire, oblanceolate with a winged petiole, not auriculate nor clasping, 2 to 18 inches long by 1 to 4 wide, the cauline 1 to 3 inches long: pedicels 2 or 3 lines long: calyx 3 lines long, the longer narrow tooth about equalling the tube; corolla 9 lines long, narrowly cylindrical, with the throat contracted, very narrow at base within the calyx, the very short obtusely lobed limb nearly erect: filaments inserted equally near the base: capsule ovate, acute, 4 lines long. — At Monterey, Nuevo Leon (961). Allied to *N. paniculata*.

NICOTIANA TRIGONOPHYLLA, Dun. In the mountains east of Saltillo (962), and in rocky places about San Luis Potosi (688 Schaffner); 660 Parry & Palmer.

NICOTIANA REPANDA, Willd. At Georgetown, Williamson County, Texas (999); 659 Parry & Palmer.

Nicotiana glauca, Linn. At San Luis Potosi (689 Schaffner), and at Guanajuato (Dugès), where it is called "Tronadora de España."

Petunia parviflora, Juss. At San Luis Potosi (612 Schaffner); 661 Parry & Palmer.

Bouchetia erecta, DC. At Lerios (852) and Soledad, Coahuila (2021), and at San Luis Potosi (611 Schaffner); 630 Parry & Palmer, in part. The linear portion of the corolla-tube is slightly longer than the tube of the calyx (longer than in any Texan specimens), but by no means so elongated as shown in the original figure of *D. procumbens*, to which species Schaffner's plants are in part referred by Hemsley, and the corolla is more expanded above.

Nierembergia angustifolia, HBK. At San Luis Potosi (610 Schaffner); 630 Parry & Palmer, in part.

Leucophyllum Texanum, Benth. At Uvalde, Texas, and Laredo on the Rio Grande, and in the intervening region (967, 968, 2011), and at Parras, Coahuila; the latter a form with broad spatulate leaves, referred to *L. minus*, Gray, and the same as 663 Parry & Palmer.

Verbascum virgatum, With. In the mountains near Morales, San Luis Potosi (742 Schaffner).

Antirrhinum maurandioides, Gray. At San Antonio, Texas (971), at Saltillo (970), and at San Luis Potosi (749 Schaffner); 665 Parry & Palmer.

Maurandia Barclayana, Lindl. In the Caracol Mountains, east of Monclova (972), in the San Miguelito Mountains, San Luis Potosi (748 Schaffner), and at Guanajuato (Dugès); 664 Parry & Palmer.

Maurandia erecta, Hemsl. in Gard. Chron. 2. 17. 22, and Bot. Biol. Centr.-Amer. 2. 441. At San Lorenzo de Laguna, Coahuila (966).

Pentstemon barbatus, Nutt. In the Sierra Madre, south of Saltillo (975), and in the Caracol Mountains, east of Monclova (973); 667 Parry & Palmer.

Pentstemon imberbis, Trautv. At Saltillo, and in the mountains east of that place (974), and in the San Miguelito Mountains, San Luis Potosi (752 Schaffner); 667½, 668 Parry & Palmer.

Pentstemon campanulatus, Willd. At Lerios in the high mountains east of Saltillo (976), and at Guanajuato (Dugès); 669 Parry & Palmer.

Pentstemon baccharifolius, Hook., var. Schaffneri, Hemsl. In the San Miguelito Mountains, San Luis Potosi (751 Schaffner); 666 Parry & Palmer.

PENTSTEMON TENUIFOLIUS, Benth. In the Morales Mountains, San Luis Potosi (753 Schaffner); 672 Parry & Palmer.

PENTSTEMON STENOPHYLLUS, Gray. In mountains near San Luis Potosi (754 Schaffner); 671 Parry & Palmer.

MIMULUS GLABRATUS, HBK. At Saltillo (977), and at San Lorenzo de Laguna, Coahuila (978, 979); 675 Parry & Palmer.

STEMODIA DURANTIFOLIA, Swartz. Near Morales, San Luis Potosi (714 Schaffner); 679 Parry & Palmer. Also a prostrate and rooting variety (?), with sessile flowers, and a broad funnelform corolla 6 lines long; between the Frio and Nueces Rivers, Texas (1053).

CONOBEA MULTIFIDA, Benth. At Sutherland Springs (980).

HERPESTIS ROTUNDIFOLIA, Pursh. At Guadalupe, Texas (981). Flowers white.

HERPESTIS MONNIERA, HBK. At San Antonio, Texas (987); 677 Parry & Palmer.

HERPESTIS CHAMÆDRIOIDES, HBK. At Guajuco (988), and at Monterey, Nuevo Leon, and near Morales, San Luis Potosi (743 Schaffner); 674 Parry & Palmer. Mostly with large yellow flowers, often twice the length of the calyx, the outer segments of which are oblong-ovate or lanceolate. 988 Palmer has been referred to *H. nigrescens*, and 674 Parry & Palmer in part to *H. radicata*, Benth. The species is a variable one, and easily includes these forms.

ILYSANTHES GRATIOLOIDES, Raf. Near Morales, San Luis Potosi (121 Schaffner); 676 Parry & Palmer.

LIMOSELLA AQUATICA, Linn. Near Morales (125 Schaffner).

VERONICA PEREGRINA, Linn. At Monterey, Nuevo Leon, and near Morales (723 Schaffner); 678 Parry & Palmer.

BUCHNERA LITHOSPERMIFOLIA, HBK. (?) Near San Luis Potosi (Schaffner, without number). Apparently a common though somewhat variable species in Mexico, and extending into Arizona (2830 Lemmon), with leafy stem 1 to 2 feet high, short rough pubescence, ovate to linear-lanceolate bracts, narrow calyx-teeth exceeding the ovate-oblong acute capsule (3 lines long), and corolla 5 or 6 lines long. Bentham identifies the Mexican plant (as represented by 100 Hartweg) with this Colombian species, though it does not wholly agree with the description. It is all referred by Hemsley to *B. elongata*, Swartz, but that species as represented in the United States and West Indies is very clearly distinguished by its more naked stems, short ovate bracts, short calyx-teeth, and obtuse capsule exceeding the calyx. It is doubtful whether *B. elongata* occurs at all in Mexico.

BUCHNERA PILOSA, Benth. (?) Near San Luis Potosi (Schaffner, with the last, without number). Lower and more slender than the last (4 to 7 inches high), pilose throughout, and with shorter calyx and corolla, the capsule 2 lines long. This may not be the plant to which the name was originally applied, and which was later referred by Bentham to *B. lithospermifolia*, but the pilose pubescence is characteristic.

SEYMERIA BIPINNATISECTA, Seem. Caracol Mountains (989).

SEYMERIA VIRGATA, Benth. In the San Miguelito Mountains, San Luis Potosi (735 Schaffner); 682 Parry & Palmer.

GERARDIA (DASYSTOMA) GREGGII. Pubescent with very short stiff spreading glandular hairs: leaves small (an inch long or less), sessile, ovate, coarsely and acutely toothed, somewhat hastately lobed at base: pedicels exceeding the leaves, curved, ascending: calyx-lobes lanceolate, acuminate, equalling or exceeding the tube; corolla pubescent, "dark buff," an inch long. — In the Sierra Madre, south of Saltillo (2024), very scanty specimens; collected also by Dr. Gregg (81). Allied to *G. pedicularia;* referred to *G. grandiflora* by Hemsley.

GERARDIA PEDUNCULARIS, Benth. At San Luis Potosi (755 Schaffner); 670 Parry & Palmer.

CASTILLEIA LANATA, Gray. At Saltillo, Coahuila (990); 689 Parry & Palmer.

CASTILLEIA TENUIFLORA, Benth. In the mountains east of Saltillo (991), and in the San Miguelito Mountains, San Luis Potosi (740 Schaffner); 692 Parry & Palmer.

CONOPHOLIS MEXICANA, Gray in herb. Distinguished from *C. Americana* by its longer and more rigid lanceolate acuminate scales, the calyx less deeply toothed, and the corolla larger (8 lines long). — In the Sierra Madre, south of Saltillo (996), and at Soledad, Coahuila, growing at the foot of oaks; 693 Parry & Palmer. It has been previously collected in New Mexico in the Organ Mountains (1461 Wright), and in the Santa Magdalena Mountains (G. R. Vasey), and in the mountains of Arizona (Rusby), and it is probably the more common species in Mexico. The plant figured by Endlicher (Iconogr. t. 81) for *C. Americana* is *C. Mexicana*, probably from Andrieux's collection.

CASTILLEIA SESSILIFLORA, Pursh. In the mountains east of Saltillo (993), and in the Sierra Madre, south of that place (992).

CASTILLEIA SCORZONERÆFOLIA, HBK. At Lerios in the high mountains east of Saltillo (2026), a tall and nearly the typical form, and the same as 107 Gregg; 690 Parry & Palmer is probably the same. Also a low annual variety, in the San Miguelito Mountains (741 Schaffner), and at Guanajuato (Dugès); 691 Parry & Palmer. Dugès gives the popular name "Flor de Milpa."

Castilleia canescens, Benth. In the mountains near San Luis Potosi (739 Schaffner), and at Guanajuato (Dugès); 688 Parry & Palmer. Approaching *C. tenuiflora.*

Orthocarpus Mexicanus, Hemsl. Bot. Biol. Centr.-Amer. 2. 463, t. 63, A., fig. 1–6. At Lerios, Coahuila, — a single specimen.

Lamoreuxia rhinanthifolia, HBK. In the San Miguelito Mountains, San Luis Potosi (750 Schaffner), and at Guanajuato (Dugès); 686 Parry & Palmer. 101 Bourgeau, referred to *L. Gutierrezii*, is the same.

Pedicularis Canadensis, Linn. In the Sierra Madre, south of Saltillo (994); 684 Parry & Palmer.

Aphyllon multiflorum, Gray. At Saltillo (995).

Aphyllon Ludovicianum, Gray. At Uvalde, Texas (2025).

Aphyllon (Nothaphyllon) Dugesii. Glabrous or very sparingly puberulent, about 3 inches high, with short scaly-bracteate stems and dense simple spikes: flowers sessile or the lower shortly pedicellate, with a pair of linear acuminate bractlets: calyx equally 5-cleft to below the middle, 5 lines long; corolla (8 lines long) bilabiate with erect lips, the upper bifid, the lower 3-parted, plicate and truncate between the segments: stigma bilamellar, the lobes lateral. — At Guanajuato (Dugès).

Utricularia denticulata, Benj. (?) Growing in mud, the spatulate leaves nearly an inch long, with occasional utricles attached to the petioles. The flowers nearly accord with Benjamin's description, but the denticulations at the apex of the broad lower lip (4 lines long) are obscure, and the palate is margined by a row of prominent tubercles. — Near Morales, San Luis Potosi (120 Schaffner); 694½ Parry & Palmer.

Pinguicula caudata, Schlecht. At Guanajuato (Dugès); 694 Parry & Palmer.

Bignonia buccinatoria, Mairet. At San Luis Potosi (746 Schaffner), and in cultivation at Guanajuato (Dugès); 695 Parry & Palmer.

Chilopsis saligna, Don. At Uvalde, Texas (1000), at Parras, Coahuila (1001), and at San Luis Potosi (745 Schaffner).

Tecoma stans, Juss. In the mountains east of Saltillo (1002), and at San Lorenzo de Laguna, Coahuila (1003).

Martynia proboscidea, Glox. At Laredo, Texas (2027).

MARTYNIA FRAGRANS, Lindl. At San Luis Potosi (747 Schaffner), and at Guanajuato (Dugès), where it is called "Toritos"; 697 Parry & Palmer.

ELYTRARIA BROMOIDES, Oersted. At Guajuco, Nuevo Leon (2029). Quite distinct from *E. tridentata*, Vahl, to which it is referred by Hemsley.

CALOPHANES DECUMBENS, Gray. Apparently the same as *C. Schiedeana*, Nees, from which *C. Jasminum-Mexicanum*, Nees, is probably not distinct. At Saltillo (1009, 2032), at Lerios in the high mountains east of Saltillo (1010), and at San Luis Potosi (647 Schaffner).

CALOPHANES LINEARIS, Gray. In the Sierra Madre, south of Saltillo (2033).

RUELLIA TUBEROSA, Linn. At Guadalupe (1006), and Sutherland Springs, Texas (1007, 2031), and at Saltillo.

RUELLIA PARRYI, Gray. At Parras, Coahuila (1008). Flowers noted as light-purple with darker veins in the throat.

STENANDRIUM DULCE, Nees. At Laredo, on the Rio Grande (1005), and at Lerios, Coahuila (2030); 703 Parry & Palmer.

SIPHONOGLOSSA PILOSELLA, Torr. At Eagle Pass (1012), and at Corpus Christi, Texas (2034), and in the mountains northeast of Monclova, Coahuila (1011); 701½ Parry & Palmer.

DIANTHERA PARVIFOLIA, Benth. & Hook. At San Antonio, Texas (1015). Also a taller and stouter very glandular-pubescent form, at Monterey, Nuevo Leon (1014), the same as 1214 Coulter. This species might perhaps well be referred to *Carlowrightia*.

JACOBINIA INCANA, Benth. & Hook. At Guajuco (997) and Monterey, Nuevo Leon (998); 704 and 704½ Parry & Palmer.

JACOBINIA MOHINTLI, Benth. & Hook. At San Luis Potosi (112 Schaffner), and at Guanajuato (Dugès). Known as "Muicle."

ANISACANTHUS WRIGHTII, Benth. & Hook. At Uvalde (2035).

ANISACANTHUS VIRGULARIS, Nees. In the mountains east of Saltillo (1016), and at San Luis Potosi (744 Schaffner); 706 Parry & Palmer. Calyx-teeth from triangular and scarcely as long as the tube to lanceolate and twice longer than the tube; flowers "scarlet."

ANISACANTHUS PUMILUS, Nees. Leaves somewhat broader than in the last, the linear calyx-teeth many times longer than the very short tube; flowers "light buff." At Parras, Coahuila (1017); 706½ Parry & Palmer.

DICLIPTERA BRACHIATA, Spreng. At San Antonio, Texas (1013), a villous form with small leaves.

TETRAMERIUM HISPIDUM, Nees. At Soledad, Coahuila (1089), and at Guanajuato (Dugès); 700 Parry & Palmer.

TETRAMERIUM ——? Low and branching, woody at base, rough-puberulent throughout: leaves linear-oblong, 6 to 12 lines long, attenuate to a short petiole: spikes short, terminal; bracts thin, narrowly ovate, rounded or subcordate at base and nearly sessile, acute: calyx a line long, the lanceolate teeth exceeding the tube; corolla 9 lines long, very narrowly tubular, pubescent, the limb 3 lines long. — In the Caracol Mountains, southeast of Monclova (1004).

LANTANA CAMARA, Linn. At Sutherland Springs, Texas (1022), and at Guanajuato (Dugès); 707 Parry & Palmer. Dugès gives the popular name "Frutilla."

LANTANA MACROPODA, Torr. At Laredo, on the Rio Grande (1029, 1030), and at Parras, Coahuila (1027); 711 Parry & Palmer, in part.

LANTANA CANESCENS, HBK. At Monterey, Nuevo Leon (1028); 708 Parry & Palmer. Identical with 2232 Berlandier, which is referred to this species by De Candolle.

LANTANA VELUTINA, Mart. & Gal. At Guanajuato (Dugès); 709 Parry & Palmer.

LIPPIA PURPUREA, Jacq. f. At Soledad, Coahuila (1023), and in the San Miguelito Mountains, San Luis Potosi (643 Schaffner). Flowers "white, becoming yellow."

LIPPIA GRAVEOLENS, HBK. At Soledad (1025) and at Monclova, Coahuila (1026).

LIPPIA (ALOYSIA) MACROSTACHYA. Shrubby, pubescent throughout with short spreading hairs: leaves broadly ovate to ovate-oblong or oblong-elliptical, truncate or slightly cordate at base, obtuse, crenately toothed, rugosely veined, densely pubescent and canescent beneath, shortly petioled, 3 to 12 lines long, often all small: spikes loose and elongated; bracts linear-lanceolate; flowers short-pedicellate or subsessile: calyx 2 lines long, the tube densely hispid and lobes narrow; corolla twice longer, "magenta-color": style shorter than the calyx. — In the mountains east of Saltillo (1032), and in the Caracol Mountains southeast of Monclova, Coahuila (1033). The same as 190 and 323 Gregg (*L. Wrightii*, var. *macrostachya*, Torr. in Bot. Mex. Bound. 127, and Gray, Syn. Fl. 2. 338), and 712½ Parry & Palmer, which is referred to *L. Wrightii*. That species has the pubescence more tomentose, the smaller flowers in shorter and closer spikes, broader bracts, and the less rugose leaves more or less cuneate at base. The Peruvian *L. scordioides* more nearly resembles *L.*

Wrightii, but has larger more oblong and more rugose leaves, narrower bracts and narrower calyx-teeth.

Lippia lycioides, Steud. At San Antonio (1035), Uvalde (1036), Bluffton (2036), and Laredo, Texas (1034), in the mountains east of Saltillo (1037), and at San Luis Potosi (646 Schaffner); 712 Parry & Palmer.

Lippia nodiflora, Michx. At Sutherland Springs, Texas (1038), at Soledad, Coahuila (1039), and at San Luis Potosi (644 Schaffner, in part).

Lippia lanceolata, Michx. At San Luis Potosi (644 Schaffner, in part); 710 Parry & Palmer, and 711 in part. A small-leaved nearly prostrate form, probably *L. reptans*, HBK.

Priva tuberosa. Root tuberous; branching from the base and decumbent, subvillous-pubescent: leaves sessile, oblong, narrowed at base, coarsely toothed mostly toward the apex, strigose-pubescent, 6 to 12 lines long: spikes short, terminal: fruiting calyx 4 lines long, pubescent, unequally toothed, contracted above the nutlets which fill the dilated base: nutlets 1½ lines long, irregularly and coarsely reticulated. — In the San Miguelito Mountains (717 Schaffner).

Verbena polystachya, HBK. At San Lorenzo de Laguna (1040), and a form with the calyx very pubescent, from the Sierra Madre, south of Saltillo.

Verbena urticæfolia, Linn. At Guanajuato (Dugès). These two species approach each other very closely.

Verbena ——? Allied to *V. polystachya.* Densely pubescent with stiff hairs, shorter and more appressed on the leaves, which are lanceolate, incised and lobed at base; panicle small. Perhaps a hybrid between *V. polystachya* or *V. urticæfolia* and *V. xutha.* At Saltillo (2037).

Verbena officinalis, Linn. A very slender somewhat strigose narrow-leaved form, at Sutherland Springs, Texas (1043), and at San Lorenzo de Laguna (1042). Also a variety (?), of similar habit, but more hirsute throughout, and the flowers larger, the slender corolla-tube twice longer than the calyx; at Guajuco, Nuevo Leon (1041). A form with the oblong-lanceolate leaves merely toothed is found in the mountains near San Luis Potosi (718 Schaffner), and at Guanajuato (Dugès). 917 Parry & Palmer is the more usual larger-leaved form of the species.

Verbena canescens, HBK. At Monterey, Nuevo Leon (1044), and at San Luis Potosi (719 Schaffner); a dwarf form, with small ovate leaves, at Laredo, Texas (2040); and a dwarf variety (?), with ovate to oblong incised leaves, bracts equalling the calyx, and large flowers (5 lines long), at Corpus Christi, Texas (2038).

VERBENA REMOTA, Benth. Annual, with slender conspicuously bracted spikes, the fruit shorter and leaves more dissected than in the last species, to which it has been referred. At San Luis Potosi (720 Schaffner); 722 Parry & Palmer. 174 Hartweg and 361 Bourgeau are the same. It has also been collected by Mr. Pringle at Gardiner's Spring in Arizona.

VERBENA CILIATA, Benth. At Corpus Christi (1046) and at Guadalupe, Texas (2039), at Monclova, Coahuila, at Monterey, Nuevo Leon (1045), and at San Luis Potosi (717 Schaffner); 718, 719 and 720 Parry & Palmer.

VERBENA XUTHA, Lehm. Sierra Madre, south of Saltillo (1047).

VERBENA BRACTEOSA, Michx. At San Lorenzo de Laguna, Coahuila (1048); 715 Parry & Palmer.

VERBENA BIPINNATIFIDA, Nutt. At Sutherland Springs (1049).

VERBENA WRIGHTII, Gray. At Lerios, in the high mountains east of Saltillo (1052), and near Morales, San Luis Potosi (716 Schaffner). Also a variety (?), with the more dissected foliage of the last species, but with the broad and short calyx-teeth of *V. Wrightii;* at Lerios, Coahuila (1050), and at Guanajuato (Dugès), and the same as 1149, 1150 Coulter, and 26 Gregg. The species appears to vary in the size of the glandular appendage to the anthers.

CALLICARPA AMERICANA, Linn. At Sutherland Springs (1054).

MENTHA ARVENSIS, Linn. At Saltillo (1061).

MENTHA ROTUNDIFOLIA, Linn. At Parras, Coahuila (1090), and near Morales, San Luis Potosi (683 Schaffner).

CUNILA SECUNDA. Herbaceous, pubescent: leaves ovate-oblong, acuminate, rounded at base, entire, very shortly petiolate, an inch long or less, finely pubescent above, canescently subtomentose beneath: inflorescence leafy, secund, the rather loose axillary pedunculate cymes about equalling the gradually reduced leaves, pubescent: calyx a line long, with short acute teeth: corolla nearly 3 lines long: stamens long-exserted. — Guanajuato (Dugès); known as "Poleo del cerro."

MICROMERIA XALAPENSIS, Benth. At Guajuco, Nuevo Leon (1055); referred by Hemsley to *M. Brownei*, Benth.

HEDEOMA DRUMMONDII, Benth. At Sutherland Springs, Texas (1058), in the Sierra Madre, south of Saltillo (1057), and in the San Miguelito Mountains (679 Schaffner); 738 Parry & Palmer.

HEDEOMA COSTATA, Hemsl. Bot. Biol. Centr.-Amer. 2. 547. At Lerios, in the high mountains east of Saltillo (1059).

HEDEOMA TENELLA, Hemsl., l. c., 549. At Guajuco, Nuevo Leon (1060); also at Saltillo, with leaves broadly ovate, and rounded or subcordate at base. The species is very near to *H. dentata*, Torr.

HEDEOMA PALMERI, Hemsl., l. c., 548, t. 69, B., fig. 6–9. In the San Miguelito Mountains, San Luis Potosi (637 Schaffner); 728 Parry & Palmer.

POLIOMINTHA GLABRESCENS, Gray in Hemsl. Bot. Biol. Centr.-Amer. 2. 549. At Soledad, Coahuila (1056). Flowers white, with purple dots on the lower lip. Resembling sage in taste and used in cooking.

SALVIA TILIÆFOLIA, Vahl. At Soledad, Coahuila (1062), and at San Luis Potosi (674 Schaffner); 743 and 746½ Parry & Palmer.

SALVIA CHAMÆDRYOIDES, Cav. In the San Rafael Mountains, San Luis Potosi (663 Schaffner); 750, 751½ and 753 Parry & Palmer. Also a form with less hoary and scarcely at all crenate leaves, at Lerios (1064) and Parras, Coahuila (1072), and in the San Miguelito Mountains, San Luis Potosi (664 Schaffner). 751 Parry & Palmer is probably a still smoother and thinner-leaved form of the species.

SALVIA FARINACEA, Benth. At Bluffton (1066), and a form with nearly entire linear leaves at Sutherland Springs, Texas (1065).

SALVIA BALLOTÆFLORA, Benth. At San Antonio, Texas (1070), at Lerios (1068), Parras (1067), and Monclova, Coahuila (1069), and in the San Rafael Mountains, San Luis Potosi (670 Schaffner).

SALVIA GREGGII, Gray. At Lerios, in the high mountains east of Saltillo (1071).

SALVIA RŒMERIANA, Scheele. In the mountains east of Saltillo (1073).

SALVIA COCCINEA, Linn. At Uvalde (1076) and at Corpus Christi, Texas (1075, nearly glabrous), and at Guajuco, Nuevo Leon (1074, very hispid and the leaves tomentose beneath).

SALVIA PENTSTEMONOIDES, Kunth. At Sutherland Springs, Texas (1077).

SALVIA REGLA, Cav. At Lerios, Coahuila (1079), at San Rafael, San Luis Potosi (665 Schaffner), and at Guanajuato (Dugès); 741 Parry & Palmer. Dugès gives the popular name "Mirto rojo del cerro."

SALVIA AZUREA, Lam., var. GRANDIFLORA, Benth. At Sutherland Springs, Texas (1091).

SALVIA GLECHOMÆFOLIA, HBK. At Lerios in the high mountains east of Saltillo (1097), and in the Sierra Madre, south of that place (1098). The foliage appears to be very variable, sometimes on the same plant, from broadly ovate-triangular in the typical form (756 Parry & Palmer), to oblong-lanceolate (as in 406 Gregg and 1115 Coulter, which are probably *S. prunelloides*, HBK.), and to linear, as in 761 Parry & Palmer and 396 Bourgeau. *S. Arizonica*, Gray, is a very closely allied species, with acuter and more coarsely toothed leaves.

SALVIA MEXICANA, Linn. At Guanajuato (Dugès). A form near to this species, but with the calyx and corolla only half as large, was collected in the Caracol Mountains, Coahuila (1096); 757, 758 Parry & Palmer.

SALVIA NANA, HBK. In the San Rafael Mountains, San Luis Potosi (680 Schaffner); 745, 746 Parry & Palmer.

SALVIA HISPANICA, Linn. At San Luis Potosi (675 and 1053 Schaffner); known as "Chia."

SALVIA ANGUSTIFOLIA, Cav., var. GLABRA, Gray. A low slender stoloniferous form, with short and broad calyx. At San Luis Potosi (672 Schaffner); 760 Parry & Palmer.

SALVIA LANCEOLATA, Brouss. In swamps near San Luis Potosi (673 Schaffner); 744 Parry & Palmer. Very fetid.

SALVIA LEUCANTHA, Cav. Near Santa Maria, San Luis Potosi (669 Schaffner).

SALVIA LASIANTHA, Benth. In the San Rafael Mountains, San Luis Potosi (671 Schaffner); 730, 731 Parry & Palmer.

SALVIA PATENS, Cav. In the San Miguelito Mountains, San Luis Potosi (676 Schaffner), and at Guanajuato (Dugès); 759 Parry & Palmer. Dugès gives the name "Pajaros azules grandes."

SALVIA FULGENS, Cav. In the mountains near Morales, San Luis Potosi (667 Schaffner); with rather small leaves and flowers. Known as "Mirto grande."

SALVIA LINDENII, Benth. At Guanajuato (Dugès).

SALVIA MICROPHYLLA, HBK. In the San Miguelito Mountains, San Luis Potosi (662 Schaffner); 747, 748 Parry & Palmer. Apparently distinct from the next.

SALVIA GRAHAMI, Benth. Leaves truncate or subcordate at base. In the mountains near San Luis Potosi (660 Schaffner); 739 Parry & Palmer. Known as "Mirto." — Also a variety (probably *S. obtusa*, Mart. & Gal.) with the leaves somewhat cuneate at base. Near Morales, San Luis Potosi (661 Schaffner; 394 and 396 of his previous collection); 754 Parry & Palmer, more tomentose; 1093 Coulter.

SALVIA AXILLARIS, Moç. & Sesse. In the mountains near San Luis Potosi (648 Schaffner); 698 Parry & Palmer; 1118 Coulter. A very peculiar species, with very much of the habit, as noted by Bentham, of a *Thymus* or *Satureia*. The long slender stems become procumbent and rooting at the nodes. The leaves vary from oblong-linear and acute to broadly oblanceolate and obtuse, rarely sparingly toothed, 3 to 5 lines long: pedicels shorter than the leaves: fruiting calyx 4 lines long; corolla very narrowly tubular, 6 to 9 lines long, the lower lip much exceeding the upper, probably pale blue or pink; anthers purple. *S. cuneifolia*, Benth. (as represented by 1118 Coulter), is apparently only a form of this species, with the rather broader leaves often toothed at the summit.

SALVIA ——? Of the *S. Grahami* group, the stouter erect stems somewhat villous-pubescent: leaves ovate-oblong, acute, cuneate or rounded at base, acutely toothed: corolla "bright magenta," 16 lines long, the very broad lower lip much exceeding the upper. — In the Sierra Madre, south of Saltillo, Coahuila (1078); 1096 Coulter, in part.

SALVIA ——? Stoloniferous and rooting at base, the erect slender stems somewhat woody, a span high, pubescent with short spreading hairs on opposite sides: leaves rather thick, nearly glabrous, ovate to oblong-ovate, cuneate at base, acutish, rather acutely toothed, 6 to 15 lines long, short-petioled; bracts subpersistent, ovate-lanceolate, acuminate, 1–2-flowered: calyx purple, dilated campanulate, 6 lines long or more, with broad acute teeth, the upper lip entire; corolla an inch long, apparently reddish-purple, broadly tubular, the lower lip a little exceeding the upper: style bearded. — In the San Rafael Mountains, San Luis Potosi (666 Schaffner); 740 Parry & Palmer.

SALVIA ——? Near *S. elegans*: stems slender, herbaceous, puberulent on opposite sides: leaves thin, on very slender petioles, very nearly glabrous, oblong-ovate, cuneate at base, crenate, 1 to 1½ inches long: calyx tubular, 4 lines long, with short acute teeth; corolla bright scarlet, 9 lines long, narrowly tubular, the broad lower lip about equalling the upper. — At Guanajuato (Dugès), and known as "Mirto rojo chico."

SALVIA ——? Stems decumbent, herbaceous, villous and pubescent, a span high: leaves broadly ovate, truncate or cordate at base, rarely subhastate, coarsely toothed or entire, obtuse or acute, an inch long or less; bracts deciduous: verticils 2–6-flowered: calyx campanulate, 3 or 4 lines long, the upper lip entire or truncate, the lower shortly bifid; corolla blue, 9 lines long, the very broad lower lip twice longer than the upper. — In the San Miguelito Mountains, San Luis Potosi (678 Schaffner).

SALVIA ——? Near *S. amarissima*, Ort. (752 Parry & Palmer), but canescently puberulent and not at all hispid. In shaded places near Morales, San Luis Potosi (677 Schaffner).

SALVIASTRUM TEXANUM, Scheele. At Sutherland Springs (1102).

MONARDA CITRIODORA, Cerv. At San Lorenzo de Laguna, Coahuila (1082), and at Guajuco, Nuevo Leon (1080).

MONARDA PUNCTATA, Linn. At Lamar, on Copano Bay, Texas (1081).

CEDRONELLA MEXICANA, Benth. In the mountains near Morales, San Luis Potosi (682 Schaffner); 762 Parry & Palmer. Known as "Touroujil."

SALAZARIA MEXICANA, Torr. At Parras, Coahuila (1083).

SCUTELLARIA DRUMMONDII, Benth. At Lamar, on Copano Bay, Texas (2042), in the Sierra Madre, south of Saltillo (1085), and in the mountains eastward (1084), and at San Miguelito in San Luis Potosi (642 Schaffner).

SCUTELLARIA WRIGHTII, Gray. At Sutherland Springs (1086) and Bluffton, Texas (1087).

BRUNELLA VULGARIS, Linn. At Lerios, Coahuila (1088); 733½ Parry & Palmer.

PHYSOSTEGIA VIRGINIANA, Benth., var. OBOVATA, Gray. At Saltillo (2043).

MARRUBIUM VULGARE, Linn. About San Luis Potosi (681 Schaffner).

STACHYS AGRARIA, Cham. & Schlecht. At Lerios (1092), in the Sierra Madre, south of Saltillo (1093), and at Guajuco (1095).

STACHYS DRUMMONDII, Benth. In the Caracol Mountains, southeast of Monclova, Coahuila (1094), and at San Luis Potosi (684 Schaffner); 733, 734 and 735 Parry & Palmer, the latter referred to *S. agraria*.

STACHYS BIGELOVII, Gray. At San Luis Potosi (685 Schaffner).

STACHYS COCCINEA, Jacq. A form with very short and broad abruptly aristate calyx-teeth. Near San Rafael, San Luis Potosi (686 Schaffner), and at Guanajuato (Dugès); 732 Parry & Palmer, the ordinary form.

ISANTHUS CÆRULEUS, Michx. At Georgetown, Texas (1103).

TETRACLEA COULTERI, Gray. In the mountains east of Saltillo (1104), and in the San Miguelito Mountains, San Luis Potosi (636 Schaffner); 726 Parry & Palmer.

Teucrium Canadense, Linn. At Saltillo, Coahuila (1099).

Teucrium Cubense, Linn. At San Lorenzo de Laguna, Coahuila (1101), at Monterey, Nuevo Leon (1100), and in the San Miguelito Mountains (687 Schaffner); 727 Parry & Palmer. 1101 is referred by Hemsley to *T. laciniatum*, Torr., which is not clearly distinguished from this species, but is perhaps best defined by the decidedly perennial root, much larger flowers, and more elongated calyx-teeth.

Plantago major, Linn. At Parras, Coahuila (1105), and a very paniculately branched form (1106).

Plantago Patagonica, Jacq. Between the Frio and Nueces Rivers, Texas (1110), and at San Luis Potosi (659 Schaffner, in part).

Plantago Mexicana, Link. A reduced depressed form, with the scapes shorter than the leaves. At San Luis Potosi (659 Schaffner, in part); 765 Parry & Palmer, at least in part. Perhaps the species should be included among the forms of *P. Patagonica*.

Plantago Virginica, Linn., var. (?) (Var. *longifolia*, Gray, Syn. Flora, 2. 392, in part.) Scapes procumbent, very short: leaves pinnatifid-toothed: capsule exceeding the sepals: seeds red, over a line long, and broader in proportion than in *P. Virginica.* — Between the Frio and Nueces Rivers, Texas (1108), at San Lorenzo de Laguna, Coahuila (1109), at Monterey, Nuevo Leon (1107), at San Luis Potosi (656 Schaffner) and in the San Miguelito Mountains (655 Schaffner). Collected also by Dr. Gregg at Buena Vista, and by Berlandier at Matamoros (2128), together with a more erect form. 763 Parry & Palmer is referred to this species. In the ordinary forms of the species the shorter sepals about equal the capsule and the brown seed is less than a line long.

Plantago hirtella, HBK., var. (?) Leaves narrowly lanceolate, attenuate into a long winged petiole, rather sparingly pubescent, entire or obscurely toothed: sepals glabrate, or somewhat pubescent on the midvein, shorter than the capsule: seeds olive-colored. — At San Luis Potosi (657 Schaffner). 400 Bourgeau and 926 Coulter (referred to *P. Virginica*), 1128 Bourgeau, and 174 Botteri appear to be the same.

Plantago caulescens. Caulescent, probably perennial, the caudex usually branching and the leafy stems 1 to 4 inches long: leaves linear, attenuate each way, silky-pubescent, 2 to 6 inches long by 1 or 2 lines wide: peduncles exceeding the leaves, erect: spikes capitate, 3 to 6 lines long: bracts ovate, acutish, shorter than the calyx, the margins scarious below: sepals 2 lines long, nearly uniform, but the inner almost wholly scarious: corolla-lobes 2 lines long, dark-brown in the centre: stamens 4, or none: style very pubescent, short or long-exserted: seeds 2. — In the San Rafael Mountains, San Luis Potosi (658 Schaffner). Mature capsules not seen.

Mirabilis Jalapa, Linn. At Guanajuato (Dugès); 775 Parry & Palmer.

Mirabilis longiflora, Linn. At Guanajuato (Dugès).

Oxybaphus Cervantesii, Sweet. In the Sierra Madre, south of Saltillo (1111). The specimens are referred by Hemsley to *O. viscosus*, but they accord fairly with the figure and descriptions, and with cultivated specimens of this species. 1314 Berlandier, 348 and 511 Gregg, and 912 Coulter are the same.

Oxybaphus glabrifolius, Vahl. At Parras, Coahuila (1112); a small-leaved form.

Oxybaphus aggregatus, Vahl. At the same locality (1113), and in the San Miguelito Mountains, San Luis Potosi (177 Schaffner); 768 Parry & Palmer.

Oxybaphus angustifolius, Sweet. Near San Miguel (179 Schaffner); 767 Parry & Palmer.

Nyctaginea capitata, Chois. At Laredo, Texas (1114).

Allionia incarnata, Linn. At San Luis Potosi (175 Schaffner).

Boerhaavia Palmeri. Annual; stems ascending from a procumbent base, sparingly branched, rough-puberulent and viscid: leaves ovate, obtuse or acute, truncate at base, ½ inch long, on short petioles: flowers shortly pedicellate in few-flowered cymes; bracts small: perianth spreading, 3 or 4 lines long, light pink: filaments exserted: fruit oblong-clavate, obtuse, glabrous, 1½ lines long, obtusely angled, channelled on the sides. — Allied to *B. linearifolia*. At Saltillo (1120).

Boerhaavia linearifolia, Gray. Leaves from linear to lanceolate. In the Sierra Madre, south of Saltillo (1121), and in the mountains northeast of Monclova, Coahuila (1122).

Boerhaavia erecta, Linn. At Monclova (1123).

Boerhaavia eriosolena, Gray. At San Lorenzo de Laguna, Coahuila (1124).

Boerhaavia viscosa, Lag. & Rodr. At San Luis Potosi (176 Schaffner).

Boerhaavia gibbosa, Pavon. (*Senkenbergia annulata*, Schauer.) At San Lorenzo de Laguna, Coahuila (1125); 771 Parry & Palmer. Considering the diversities in the inflorescence, fruit and foliage, which occur in the other species of *Boerhaavia*, there seems to be too little reason for separating the genus *Senkenbergia*, especially if it be made to include *B. spicata*, etc., as is done by Hook. f. in Benth. & Hook. Gen. Pl. 3. 5. Farther division of the genus would be equally justifiable.

ACLEISANTHES LONGIFLORA, Gray. Trailing; flowers white with a purplish tinge, rather fragrant. At Laredo, on the Rio Grande (1115), and at Parras, Coahuila (1116).

ACLEISANTHES BERLANDIERI, Gray. Flowers white, fragrant. At Uvalde, Texas (1117).

SELINOCARPUS PALMERI, Hemsl. in Bot. Biol. Centr.-Amer. 3. 6, t. 70. At San Lorenzo de Laguna, Coahuila (1118).

SELINOCARPUS ANGUSTIFOLIUS, Torr. Same locality (1119).

PENTACÆNA POLYCNEMOIDES, Bartl. (*P. ramosissima*, Hook. & Arn.) At San Luis Potosi (129 Schaffner); 64 Parry & Palmer.

ACHYRONYCHIA PARRYI, Hemsl. Near Morales, San Luis Potosi (132 Schaffner); 53 and 64½ Parry & Palmer.

PARONYCHIA MEXICANA, Hemsl. At San Luis Potosi (133 Schaffner); 65 Parry & Palmer.

CORRIGIOLA ANDINA, Trian. & Planch. At San Luis Potosi (136 Schaffner); 54 Parry & Palmer.

CELOSIA PANICULATA, Linn. At San Antonio, Texas (1147).

CELOSIA PALMERI. Glabrous, the herbaceous branching stems about 2 feet high: leaves lanceolate, acute, somewhat hastately lobed, cuneate at base and shortly petioled, ½ to 2 inches long: flowers sessile, rather crowded in short terminal naked panicles; bracts broadly ovate, acute, a third to one half as long as the brownish lanceolate acute many-nerved sepals (2½ lines long): stigmas 2.—At Monclova, Coahuila (1148); also in the Parry & Palmer collection (1144), collected on the route from San Luis Potosi to Tampico. It is allied to *C. paniculata* and *C. virgata*, and is referred doubtfully to the latter by Hemsley. It differs in its foliage, inflorescence, and broader and less acuminate bracts and sepals, the latter with more numerous and fainter nerves.

AMARANTUS SPINOSUS, Linn. At Laredo (1126).

AMARANTUS CHLOROSTACHYS, Willd. At the same locality (1127); 786 Parry & Palmer is referred to this species.

AMARANTUS RETROFLEXUS, Linn. At Parras, Coahuila (1128, 2043bis); 785 and 785½ Parry & Palmer.

AMARANTUS POLYGONOIDES, Linn. At Guadalupe, Texas (1129).

AMARANTUS ALBUS, Linn. A *Scleropus* state (the same as 582 Wright, 1849, in part), corresponding to *Scleropus crassipes*, Moq., which is a similar state of the last species.

Amarantus Palmeri, Watson. The ordinary erect form, 6 to 7 feet high, and also procumbent. At San Luis Potosi (886 Schaffner); 786 Parry & Palmer. Popularly known as "Quelite," and used as a substitute for spinach. 785 Schaffner, from the same locality, is a form with very slender spikes and more attenuate bracts. 786½ Parry & Palmer, referred to *A. Blitum,* Linn., is *A. Wrightii,* Watson.

Acnide tamariscina, Gray. The staminate form. In the region west of San Antonio, Texas (1131).

Guilleminea illecebroides, HBK. At San Luis Potosi (789 Schaffner), and at Guanajuato (Dugès); 787 and 788½ Parry & Palmer.

Cladothrix lanuginosus, Nutt. At Laredo, on the Rio Grande (1188), and at San Lorenzo de Laguna, Coahuila.

Alternanthera Achyrantha, R. Br. At San Antonio, Texas (1145), at San Luis Potosi (881 Schaffner), and at Guanajuato (Dugès); 788 Parry & Palmer, in part. Known as "Tianguis" (Dugès), or "Trianguis Pepotta" (Schaffner). 1143 Parry & Palmer is var. *leiantha,* Seub.

Gossypianthus rigidiflorus, Hook. At Bluffton (1143), and at Laredo, Texas (1144); 788 Parry & Palmer, in part. The filaments have a dilated deltoid base, and it is therefore not probable that *G. tenuifolius* is distinct, as was pointed out by Dr. Torrey in Bot. Mex. Bound. 180.

Gomphrena tuberifera, Torr. At Soledad, Coahuila (1132).

Gomphrena decumbens, Jacq. (?) At San Luis Potosi (880 Schaffner), and at Guanajuato (Dugès). The same as 789 Parry & Palmer, 1371 Coulter, and 633 Bourgeau, which are referred to this species, though differing in various respects from the original description and figure.

Frœlichia Floridana, Moq. At Sutherland Springs (1139).

Frœlichia gracilis, Moq. At Bluffton, Texas (1140).

Frœlichia interrupta, Moq. A variety with narrowly oblanceolate leaves 2 or 3 inches long. In the Sierra Madre, south of Saltillo (1141), and in the Caracol Mountains, southeast of Monclova (1142). The more usual form, with ovate to obovate leaves, was collected in the Morales Mountains, San Luis Potosi (877 Schaffner), and at Guanajuato (Dugès); 793 Parry & Palmer. Known at Guanajuato as "Elotitos."

Hebanthe Palmeri. Climbing; stem angled, the young branches and leaves sparingly pubescent with very short rufous appressed hairs, becoming glabrous: leaves small, ovate to lanceolate, obtuse or acute, on very short petioles: spikes 3 to 5 lines long, in short axillary and terminal racemes, 1 to 3 inches long; bracts glabrous, scarious, rounded and concave: flowers globose; basal hairs very copious; perianth-segments somewhat villous, ovate: filaments very short; staminodia none: ovary glabrous; stigmas subulate, stout, nearly sessile: seed subglobose; cotyledons broad. — At Guajuco, Nuevo Leon (1138). Mentioned as probably distinct by Hemsley, but under a wrong number. Fully developed leaves are wanting.

IRESINE CASSINÆFORMIS, Schauer in Linnæa, 19. 709 (?) At Monterey, Nuevo Leon (1133). Agreeing but imperfectly with the description. Leaves only slightly roughish-puberulent above, densely white-tomentose beneath, 1 to 3 inches long, oblong-lanceolate, acute or acuminate, cuneate at base: panicle ample, the fruiting rather dense and smaller: sterile flowers nearly glabrous, a line long, white and scarious, the staminodia linear, and the oblong-obovate ovary without stigmas; fertile flowers with very thin equal glabrous bracts half the length of the somewhat rigid oblong obtuse sepals; hairs mostly basal: utricle oblong.

IRESINE LATIFOLIA, Benth. & Hook. At Monterey, Nuevo Leon (1134), and at San Luis Potosi (873 Schaffner); 792 Parry & Palmer.

IRESINE CELOSIOIDES, Linn. A form with rather large flowers in dense panicles, the leaves 1 or 2 inches long, acute or but slightly acuminate. At Georgetown (1135) and at Uvalde, Texas (1137), and in the Caracol Mountains, southeast of Monclova, Coahuila (1136); 792½ Parry & Palmer.

IRESINE ——? An imperfect specimen of a species allied to *I. latifolia*, but distinct from it. In all the flowers examined the ovary had three stigmas. At Guanajuato (Dugès).

IRESINE ——? The white clustered spikes in long-peduncled panicles, and the very narrow and thin sepals very densely villous. In the San Miguelito Mountains (876 Schaffner); 791 Parry & Palmer, in part.

DICRAURUS DIFFUSUS, Hook. f. In woods near Morales, San Luis Potosi (878 Schaffner); 790 Parry & Palmer.

CHENOPODIUM FŒTIDUM, Linn. In the Sierra Madre, south of Saltillo (1150), and at San Luis Potosi (853 Schaffner). *C. cornutum*, Benth. & Hook. (*Teloxys cornuta*, Torr.), to which 778 Parry & Palmer may be referred, appears to be distinguished by its smoothness and by the firmer and more distinctly appendaged sepals.

Chenopodium Berlandieri, Moq. A farinose form with small hastate-ovate leaves. At Parras, Coahuila (1151); 780 Parry & Palmer, in part.

Chenopodium murale, Linn. In the streets of Corpus Christi, Texas (1152).

Chenopodium Fremontii, Watson. At San Luis Potosi (851 Schaffner).

Chenopodium ambrosioides, Linn. Various forms. At San Antonio, Texas (1154), at San Lorenzo de Laguna, Coahuila (1153), at San Luis Potosi (852 Schaffner), and at Guanajuato (Dugès), where it is known as "Epazote"; 779½ Parry & Palmer.

Chenopodium stellatum. Erect, low (3 or 4 inches high), branched and leafy, glandular-pubescent: leaves entire, linear, obtuse, attenuate to the base, 3 to 9 lines long: flowers small, in numerous axillary subcircinate spikes shorter than the leaves; calyx 6–8- (usually 7-) parted, the narrow segments becoming strongly carinate and somewhat winged on the back, covering the very small erect seed. — In the mountains northeast of Monclova, Coahuila (1155). Allied to *C. carinatum.*

Atriplex parvifolia, HBK. (?) According very well with the description, except that the fruiting bracts are usually not muricate. At Parras, Coahuila (1156), and at San Luis Potosi (36 Schaffner); 779 Parry & Palmer, referred to *A. arenaria*, and 780, in part.

Atriplex acanthocarpa, Watson. At Guadalupe, Texas (1157). Also at San Lorenzo de Laguna, Coahuila (1161), a stouter variety with thicker, densely scurfy, and more sinuate-toothed and undulate leaves. It was collected by Dr. Gregg at Bolson de Mapimi and named *Obione pachylepis* by Torrey in herbarium.

Atriplex Texana, Watson. At Guadalupe (1158) and at Corpus Christi, Texas (1159). 407 Bourgeau and 436 of Schaffner's previous collection are very similar, but with more narrowly margined and less crested fruit, and are probably *A. linifolia*, Humb. & Bonpl., and *A. polygama*, Sesse.

Atriplex oppositifolia, Watson. At Corpus Christi (1160).

Atriplex canescens, James. At Laredo, on the Rio Grande, at San Lorenzo de Laguna and Parras, Coahuila (1163), and at San Luis Potosi (35 Schaffner); 782 and 783 Parry & Palmer.

Eurotia lanata, Moq. In the Sierra Madre, south of Saltillo (1164).

Corispermum hyssopifolium, Linn., var. microcarpum, Watson. At Laredo, Texas (1165).

SUÆDA DIFFUSA, Watson. At Saltillo, Coahuila (1167); 778½ Parry & Palmer.

SUÆDA TORREYANA, Watson (?) At Parras, Coahuila (1168). A very doubtful form, collected also by Gregg at Cienega Grande.

BOUSSINGAULTIA BASELLOIDES, HBK. In the Morales Mountains, San Luis Potosi (Schaffner); cultivated.

RIVINA LÆVIS, Linn. At San Antonio, Texas (1170), and at Guanajuato (Dugès). Nearly smooth, large-flowered, and with loose racemes, and perhaps to be so distinguished as only a variety of *R. humilis*, to which species 776 Parry & Palmer is to be referred.

PHYTOLACCA OCTANDRA, Linn. At San Luis Potosi (887 Schaffner); 777 Parry & Palmer.

PHYTOLACCA MEXICANA, Sweet. Dugès sends imperfect flowering specimens, with fifteen stamens and about eight styles, probably of this species (and *P. purpurascens*, Br. & Bouché), and not to be referred to *P. icosandra*. Its popular name is "Congueran." It is the *P. octandra*? of Hook. & Arn. Bot. Beechey, collected by Barclay at Manzanilla and by Sinclair at San Blas, Tepic.

ERIOGONUM LONGIFOLIUM, Nutt. At Sutherland Springs (1171).

ERIOGONUM JAMESII, Benth. At Lerios, in the high mountains east of Saltillo (1172).

ERIOGONUM TENELLUM, Torr. At Parras (1173); and var. CAULESCENS, Torr. & Gray, at Soledad, Coahuila (1174).

ERIOGONUM ATRORUBENS, Engelm. In the Sierra Madre, south of Saltillo (1175).

ERIOGONUM GREGGII, Torr. & Gray. In the same locality (1176).

ERIOGONUM ANNUUM, Nutt. At Bluffton, Texas (1177).

ERIOGONUM MULTIFLORUM, Benth. At Sutherland Springs (1178).

ERIOGONUM CILIATUM, Torr. In the mountains east of Saltillo, Coahuila (2088). Referred by Hemsley to *E. atrorubens*, Engelm.

ERIOGONUM ABERTIANUM, Torr. Near San Rafael, San Luis Potosi (873 Schaffner); 795 Parry & Palmer.

ERIOGONUM WRIGHTII, Torr. In the San Miguelito Mountains, San Luis Potosi (874 Schaffner); 796 Parry & Palmer.

POLYGONUM AVICULARE, Linn. At San Antonio, Texas (1179).

POLYGONUM PENNSYLVANICUM, Linn. At Sutherland Springs, Texas (1180), and near Morales, San Luis Potosi (882 Schaffner).

POLYGONUM PERSICARIA, Linn. Near Morales (883 Schaffner).

POLYGONUM ACRE, Linn. At San Luis Potosi (884 Schaffner).

RUMEX CRISPUS, Linn. At Parras, Coahuila (1181), near Morales (903 Schaffner), and at San Luis Potosi (907 Schaffner).

RUMEX BERLANDIERI, Meissn. At San Lorenzo de Laguna, Coahuila (1182).

RUMEX MEXICANUS, Meissn. At San Luis Potosi (904 and 906 Schaffner); 794 Parry & Palmer, apparently.

ANTIGONON LEPTOPUS, Hook. & Arn. At Guanajuato (Dugès). Commonly known as "Coamecatl."

ARISTOLOCHIA BREVIPES, Benth. (*A. Wrightii*, Seem.) In the Sierra Madre, south of Saltillo (1183).— Var. ACUMINATA is subtomentose, instead of villous-pubescent, with the leaves narrow and usually long-acuminate (1 to 2½ inches long), the basal lobes narrower and often elongated. It was collected by Wright (1701) in New Mexico, by Thurber (1025) in Sonora, by Lemmon (272) in the Santa Catalina Mountains, Arizona, and by Pringle near Camp Lowell; it is also in Schaffner's previous collection (47), from the mountains near San Luis Potosi. 766 Parry & Palmer in its foliage connects with the typical form.

ARISTOLOCHIA PARDINA, Duchartre. At Colima, where it is known as "Huaco" (Dugès).

ANEMOPSIS CALIFORNICA, Hook. At Parras, Coahuila (1184), near Santa Maria del Rio, San Luis Potosi (532 Schaffner), and at Guanajuato (Dugès); "Yerba del Manzo."

PEPEROMIA UMBILICATA, Ruiz & Pavon, var. MACROPHYLLA, C. DC. At San Luis Potosi (108 Schaffner), and at Guanajuato (Dugès); 802 Parry & Palmer.

PERSEA GRATISSIMA, Gaertn., var. SCHIEDEANA, Meissn. In the mountains near Santa Maria del Rio (116 Schaffner), and at Guanajuato (Dugès). Known as "Ahuacate."

LITSEA GLAUCESCENS, HBK., var. SUBSOLITARIA, Meissn. In the San Miguelito Mountains, San Luis Potosi (710 Schaffner), and at Guanajuato (Dugès); 798 Parry & Palmer.

LAURANTHUS CALYCULATUS, DC. At Guanajuato (Dugès); 800 Parry & Palmer. The specimens accord with the figure and description. They seem also to be the same as 18 Coulter and 342 Andrieux, which are referred to *L. Schiedeanus*, Cham. & Schlecht. That species, however, is described as having the leaves attenuate at the apex and the flowers three inches long. The fruit with the present specimens is oblong-obovate, 5 lines long; embryo with 4 to 6 cotyledons. Known as "Ingerto.'

EUPHORBIA PROSTRATA, Ait. At Sutherland Springs, Texas (1196), at Monclova, Coahuila (1193), and at Monterey, Nuevo Leon (1189); 816½ and 818 Parry & Palmer.

EUPHORBIA SERPENS, HBK. At San Lorenzo de Laguna, Coahuila (1192, 1195); 820 Parry & Palmer. Also var. RADICANS, Engelm., at Corpus Christi (1190), and Sutherland Springs (1191).

EUPHORBIA SERRULA, Engelm. At San Lorenzo de Laguna (1194); 810 Parry & Palmer, in part.

EUPHORBIA POLYCARPA, Benth. At Monterey, Nuevo Leon (1197), and at Juraz, Coahuila (1204). Also at San Lorenzo de Laguna (1205), a stout form, from a thick woody root, the involucres nearly smooth and unappendaged, and the capsules less pubescent.

EUPHORBIA MACULATA, Linn. At Bluffton (1198), Georgetown (1202), and Sutherland Springs, Texas (1208, 2048, 2049), and at Parras, Coahuila (1210).

EUPHORBIA VILLIFERA, Scheele. In the Caracol Mountains (1199); and in the Sierra Madre, south of Saltillo, a more naked form with coarsely toothed leaves, the same as 2084 Berlandier.

EUPHORBIA GLYPTOSPERMA, Engelm. At Laredo, on the Rio Grande (1200), Guadalupe (1201), and Sutherland Springs (2047).

EUPHORBIA FENDLERI, Torr. & Gray. At Sutherland Springs, Texas (1203).

EUPHORBIA ADENOPTERA, Bertol. At Soledad, Coahuila (1206), at Morales (855 Schaffner) and San Luis Potosi (1034 Schaffner, in part), and at Guanajuato (Dugès); 816 and 819 Parry & Palmer.

EUPHORBIA ALBOMARGINATA, Torr. & Gray. At Sutherland Springs (1207), and west of San Antonio, Texas (1212).

EUPHORBIA PRESLII, Guss. At Sutherland Springs (2050) and Bluffton, Texas (2051), at Parras (1209) and Monclova, Coahuila (1211), at San Luis Potosi (856 Schaffner, in part), and at Guanajuato (Dugès); 808 and 814 Parry & Palmer. Somewhat variable in pubescence, and quite so in the markings of the seeds, Schaffner's and Dugès' specimens having the seeds deeply pitted, rather than rugose. Popularly known as "Yerba de la Golondrina."

EUPHORBIA CUMBRÆ, Boiss. Agreeing very well with the description, but taller (6 to 9 inches high), the involucres pedicellate, and capsule angled. In the mountains north of Monclova (1213).

EUPHORBIA ZYGOPHYLLOIDES, Boiss. At Sutherland Springs, Texas (1214).

EUPHORBIA GRAMINEA, Jacq. At Parras, Coahuila (1215, 1216), and at San Luis Potosi (863 Schaffner).

EUPHORBIA ANTISYPHILITICA, Zucc. In the mountains west of Saltillo (1217), and about San Luis Potosi (867 Schaffner); 821 Parry & Palmer.

Euphorbia (Poinsettia) exclusa. Annual, erect, more or less tomentose throughout, a foot high, the strict rather stout branches becoming naked: leaves scattered, narrowly linear, attenuate to each end, entire or serrulate, the margin becoming revolute, 1 to 1½ inches long: involucres in a short terminal subsessile cyme, very shortly pedicelled, tomentose, hemispherical, the broad truncate lacerate lobes united at base in front of the very short orbicular tomentose glands: styles very short, stout, bifid: capsule tomentose, 2 lines long: seed carunculate, oblong-quadrate, obsoletely tuberculate and rugose, 1½ lines long. — At San Lorenzo de Laguna, Coahuila (1218). Nearly allied to *E. eriantha.*

Euphorbia marginata, Pursh. At San Antonio, Texas (1219).

Euphorbia barbellata, Engelm. At Uvalde, Texas (1220).

Euphorbia heterophylla, Linn., var. graminifolia, Engelm. At Uvalde (1221) and Georgetown, Texas (2052). Also a peculiar form, with the linear-lanceolate leaves sharply serrate and near the base coarsely toothed; at San Luis Potosi (859 Schaffner).

Euphorbia dentata, Michx. At Sutherland Springs, Texas (1223), at Juraz, Coahuila (1222), and at Monterey, Nuevo Leon. Also var. lasiocarpa, Boiss., at Parras, Coahuila (1224), and in the San Miguelito Mountains, San Luis Potosi (858 Schaffner); 805 Parry & Palmer.

Euphorbia campestris, Cham. & Schlecht. In the Sierra Madre, south of Saltillo (1225, 2054), and at Parras, Coahuila (1227), at Guajuco, Nuevo Leon (1226), in the San Rafael Mountains (865 Schaffner), and at San Miguelito (864 Schaffner) and San Luis Potosi (866 Schaffner), and at Guanajuato (Dugès); 803 Parry & Palmer. Different forms, but apparently all belonging to this species. Dugès gives the popular name "Yerba del Coyote."

Euphorbia Lathyris, Linn. At Saltillo, Coahuila (2059); by a garden fence.

Euphorbia angusta, Engelm. At Sutherland Springs, Texas.

Euphorbia acuta, Engelm. At Juraz, Coahuila.

Euphorbia (Cyttarospermum) tenera. A slender annual, about a foot high, sparingly pubescent, several times dichotomous: leaves thin, opposite, without stipular glands, shortly petiolate, elliptical, acutish at each end, 4 to 8 lines long: peduncles in the forks and terminal, solitary, 1 to 6 lines long: involucres glabrous, the tube nearly a line long, pubescent within, with oblong entire lobes; glands prominent upon a broad stipe, with an oblong-ovate subconcave entire whitish appendage, the whole as long as the tube: ovary slightly pubescent; styles bifid. — Near *E. delicatula*, Boiss. In the Sierra Madre, south of Saltillo (2053).

EUPHORBIA SERPYLLIFOLIA, Pers. At San Luis Potosi (854 Schaffner, in part, and 1034 Schaffner, in part); 810, in part, and 811 Parry & Palmer.

EUPHORBIA AMMATOTRICHA, Boiss. (?) Very variable, annual or doubtfully perennial, glaucous and more or less villous, the leaves from round-cordate to linear-oblong, often coarsely toothed; the reniform glands with more or less conspicuous white appendages; capsule comparatively large, acutely angled; seed smooth. — At San Luis Potosi (854 Schaffner, in part, and 856, in part); 813 Parry & Palmer.

EUPHORBIA RADIANS, Benth. In the San Miguelito Mountains (857 Schaffner); 822 Parry & Palmer.

EUPHORBIA SPHÆRORRHIZA, Benth. At Morales, San Luis Potosi (861 Schaffner); 807 Parry & Palmer.

EUPHORBIA CALYCULATA, HBK. (?) At Guanajuato (Dugès). An imperfect specimen, with leaves (4 inches long) very acute and bristle-tipped, the lower side with the petiole and stem more or less tomentose; peduncles short and stout; floral bracts white, ovate, sessile, 4 lines long; lobes of the involucre broad and short, fimbriate; style short and stout.

EUPHORBIA (ZYGOPHYLLIDIUM) BIFORMIS. Stems herbaceous from a tuberous root, a foot high or less, slender, dichotomous, puberulent: glandular stipules minute or obsolete; leaves opposite, shortly petioled, linear (½ to 2 inches long by 1 or 2 lines broad), or narrowly ovate-oblong (4 to 10 lines long by 2 to 4 broad), entire, obtuse, rounded or cuneate at base: peduncles short, axillary and terminal: involucres with inflexed quadrate lacerate lobes; appendages 4, rounded, whitish: styles short, thick, bifid: capsule 1½ lines broad: seeds without caruncle, ovate, ⅔ of a line long, irregularly pitted and tuberculate. — In the San Miguelito Mountains, San Luis Potosi (860 and 862 Schaffner); 806 Parry & Palmer. Collected by Schaffner in two forms, but differing only in foliage, as described.

PHYLLANTHUS POLYGONOIDES, Spring. In the Caracol Mountains (1228), at Monclova, Coahuila, and at Monterey, Nuevo Leon (1229.)

JATROPHA BERLANDIERI, Torr. At Laredo, Texas (1231).

JATROPHA SPATHULATA, Muell. Arg., var. SESSILIFLORA, Muell. At the same locality (1234), and at San Luis Potosi (Schaffner); 830 Parry & Palmer. The leaves on the more vigorous shoots are usually deeply 3-lobed, as in the typical form. Dr. Gregg gives the popular name "Sangre de Drago" or "Sangregrada"; according to Schaffner it is known as "Sanope Drau." The root is said to be used as a remedy for diarrhœa and dysentery.

Croton fruticulosus, Torr. At Uvalde, Texas (1235).

Croton Torreyanus, Muell. Arg., var., with the leaves mostly blunt and mucronulate at the apex. At Monclova, Coahuila (1236). 201 Gregg and 640 Wright are the same.

Croton maritimus, Walt. At Corpus Christi, Texas (1237).

Croton capitatus, Michx., var. Lindheimeri, Muell. Arg. At Laredo, on the Rio Grande (1238).

Croton Palmeri. Annual, with the habit of *C. glandulosus*, a foot high or more, repeatedly dichotomous, stellately pubescent and roughish: leaves without glands or stipules, lanceolate, acute, roundish or subcuneate at base, entire, ½ to 1½ inches long, on slender petioles: flowers clustered, male and female together, in the axils, shortly pedicelled: calyx-lobes 5, in the female flowers oblanceolate, but slightly unequal, becoming 2 or 3 lines long: stamens 8: styles 2-parted, the filiform lobes pubescent: capsule depressed-globose, equalling the calyx, pubescent: seeds finely rugulose, 1½ lines long. — At Soledad, Coahuila (1239).

Croton gracilis, Muell. Arg. At Monterey, Nuevo Leon (1240), and at San Luis Potosi (871 Schaffner); 828 Parry & Palmer. Known as "Yerba del Zorillo."

Croton Lindheimerianus, Scheele in Linnæa, 25. 580, not Muell. Arg. (*C. ellipticus*, Muell. Arg. in DC. Prodr. 15^2. 688, not Nutt. *C. eutrigynus*, Gray, Manual.) At Laredo, Texas (1241).

Croton Texensis, Muell. Arg. (*C. virens*, Muell. Arg.) At Bluffton, Texas (1242).

Croton monanthogynus, Michx. (*C. ellipticus*, Nutt.) At San Antonio, Texas (1243).

Croton glandulosus, Linn., var. Lindheimeri, Muell. Arg. At Sutherland Springs, Texas (1244). Also var. septentrionalis, Muell., at Lamar, on Copano Bay, Texas (2056).

Croton corymbulosus, Engelm. (*C. Lindheimerianus*, Muell. Arg. in DC. Prodr. 15^2. 579, not Scheele.) At Soledad (1245).

Croton morifolius, Willd., var. sphærocarpus, Muell. Arg. At Guanajuato and Penjamo (Dugès); 829 Parry & Palmer. Known as "Palillo."

Croton ——? Low and shrubby, with roughish stellate pubescence, close and subtomentose on the young leaves and branches: leaves ovate to oblong-ovate, obtuse, subcordate at base, becoming rigid and rough above, more densely pubescent beneath, ½ to 1½ inches long; petioles 2 to 4 lines long; glands none and stipules obsolete: racemes short (6 to 10 lines), the pistillate flowers few and solitary at the base: stamens 15: petals villous at base: pistillate calyx a line long: styles once parted: capsule densely stellate-pubescent, nearly 4 lines long, the smooth seeds nearly 3 lines long. — Of the *Eucroton* section and allied to the last species, apparently undescribed. In the San Miguelito Mountains, San Luis Potosi (872 Schaffner).

ARGYTHAMNIA HUMILIS, Muell. Arg. At San Antonio (1248), Laredo (1247), and Corpus Christi, Texas (1230).

ARGYTHAMNIA NEO-MEXICANA, Muell. Arg. At Monclova (1246), and San Lorenzo de Laguna, Coahuila (1250).

ARGYTHAMNIA MERCURIALINA, Muell. Arg. (?) The petals of the male flowers ovate with a broad short claw, acute, somewhat undulate, the glands wanting or wholly adnate to the thick stamineal column: petals of the female flowers obsolete and glands very small; fruiting calyx-lobes only 1½ lines long: pubescence scanty, appressed. — At Sutherland Springs, Texas (1249).

BERNARDIA MYRICÆFOLIA, Watson. At Monclova, Coahuila (322, 1232).

BERNARDIA (?) FASCICULATA. A much-branched leafy shrub, 5 feet high or more, apparently diœcious, the young branches canescent with a short close silky pubescence: leaves in numerous sessile fascicles, or alternate on young shoots, rather thick, spatulate or oblanceolate, 2 to 4 lines long, glabrous or nearly so, entire: male flowers fascicled, on slender pedicels about a line long, glabrous; sepals 5; stamens 3 to 5, free, surrounding a fleshy disk or rudimentary ovary, the short-oblong terete anther-cells attached near the top: female flowers very nearly sessile; calyx very small: ovary appressed-silky; stigmas thick, obscurely lobed: capsule sessile or nearly so, puberulent, subglobose with a deep depression at base, not deeply lobed, and cocci 2-valved, 3 or 4 lines long: seeds flattened-obovate, smooth, with a prominent caruncle partially covered by the raised testa. — An anomalous species of doubtful position, only provisionally referred to *Bernardia*. It appears to be allied to *Bernardia* and, perhaps more nearly, to *Adelia*, but differs essentially from both. In the mountains northeast of Monclova, Coahuila (1233); collected also by Gregg on the plains southwest of San Pablo, in April, 1847, — staminate specimens only, — and by Thurber (837), at Saucillo, Chihuahua, in fruit. Palmer's specimens, collected in September, are in fruit and with pistillate flowers in some of the leaf-fascicles.

ACALYPHA PHLEOIDES, Cav. At Saltillo (1251), and in the San Miguelito Mountains, San Luis Potosi (33 Schaffner).

ACALYPHA LINDHEIMERI, Muell. Arg. At Monclova, Coahuila; 826 and 826½ Parry & Palmer, referred to the last species.

ACALYPHA RADIANS, Torr. West of San Antonio, Texas (1253).

ACALYPHA ANEMIOIDES, HBK. At San Luis Potosi (31 Schaffner); 825 Parry & Palmer.

ACALYPHA NEO-MEXICANA, Muell. Arg. At San Luis Potosi (32 Schaffner); 737 Parry & Palmer, referred to *A. Virginica*, which probably does not occur in Mexico.

ACALYPHA VAGANS, Cav., var. GLANDULOSA, Muell. Arg. At San Luis Potosi (34 Schaffner). Quite variable. Probably the same as the plant thus referred by Mueller, but apparently as distinct from Cavanilles' species as several of the species of this group in the Prodromus.

TRAGIA NEPETÆFOLIA, Cav. At Monterey, Nuevo Leon. — Also a variety with only sinuate leaves, rarely toothed toward the base, with a deep sinus and rounded basal lobes; at Laredo, on the Rio Grande (1254). — Also var. (?) ANGUSTIFOLIA, Muell. Arg.; at Sutherland Springs, Texas (2057). The narrow leaves are nearly sessile (as in Berlandier's specimen).

TRAGIA URTICÆFOLIA, Michx. At Guanajuato (Dugès), where it is known as "Ortiguilla"; 827 Parry & Palmer, referred to *A. stylaris.* It is not easy to clearly separate this species (from which *A. macrocarpa*, Willd., is certainly distinct) from the last.

STILLINGIA SANGUINOLENTA, Muell. Arg., var. ANGUSTIFOLIA, Muell. At Guajuco, Nuevo Leon (1255); referred by Hemsley to *S. sylvatica.* With staminate flowers only, and many of the leaves alternate.

STILLINGIA ANGUSTIFOLIA, Engelm. in herb. (*S. sylvatica*, vars. *angustifolia* and *linearifolia*, Muell. Arg.) Distinguished from *S. sylvatica* by the narrowly linear very acute leaves, the somewhat smaller capsule with flatter gynobase, and the quite smooth seed. — At Sutherland Springs, Texas (1256).

STILLINGIA TORREYANA, Watson. Apparently perennial. It is nearly certain that *Sebastiana Treculiana*, Muell. Arg., is not distinct. At Eagle Pass, Texas (1257), and at Monterey, Nuevo Leon (1258).

CALLITRICHE AUSTINI, Engelm. Near Morales, San Luis Potosi (123ª Schaffner, in part).

CALLITRICHE HETEROPHYLLA, Pursh. With the last, and under the same number.

Callitriche verna, Linn. Same locality (123^b Schaffner).

Ulmus crassifolia, Nutt. At San Antonio, Texas (1259).

Celtis reticulata, Torr. At Uvalde, Texas (1260). A form with small entire leaves (1 to 1½ inches long), less hispid than usual.

Celtis Berlandieri, Klotzsch. At Monterey, Nuevo Leon (1261). Not clearly distinguished from *C. Mississippiensis*, Bosc.

Celtis pallida, Torr. Referred by Planchon to *C. Tala*, Gill., from which it differs in at least the fine cinereous pubescence and the rough and blunter (usually obtuse) leaves. At Laredo, Texas (159).

Cannabis sativa, Linn. At Guanajuato (Dugès); known as "Marihuana."

Urtica spirealis, Blume, var. (?) Near *U. Magellanica*, Poir., but with smaller stipules (linear, 2 lines long), and with smaller and less crowded flowers and fruit. At Guajuco, Nuevo Leon (1262).

Urtica urens, Linn. At Corpus Christi, Texas (1264); 833 Parry & Palmer.

Urtica chamædryoides, Pursh. At Monterey (1265).

Bœhmeria cylindrica, Willd. At San Antonio, Texas (1263).

Parietaria officinalis, Linn. (?) Referred to this species at Kew, but perhaps distinct. At Guajuco, Nuevo Leon (1266).

Parietaria Floridana, Nutt. Considered by Weddell as a variety, first of *P. debilis*, and afterwards of *P. Pennsylvanica;* probably distinct from both. In the mountains east of Saltillo (1267), and in the San Miguelito Mountains, San Luis Potosi (39 Schaffner); 832 Parry & Palmer.

Platanus Mexicana, Moric. Distinguished from *P. racemosa* by the shorter and broader lobes of the leaves (densely white-tomentose beneath), and by the larger fruit with the akenes tomentose to the summit. At Monterey, Nuevo Leon (1268); 834 Parry & Palmer.

Platanus Lindeniana, Mart. & Gal. Differing from the last in the more ferruginous and less persistent tomentum, and in the long-acuminate leaf-lobes. At Monclova, Coahuila (1269); referred to *P. racemosa.*

Carya olivæformis, Nutt. At Georgetown, Texas (1271, 1272, 1273, 2005); 835½ Parry & Palmer (the same number is cited by Hemsley under *C. Mexicana*, which should be 834½).

Juglans rupestris, Engelm. At Uvalde, Texas (1270).

Juglans nigra, Linn. At Georgetown, Texas (2002).

Quercus virens, Ait. At Sutherland Springs (1274), Laredo (1276), Uvalde (1279), and Georgetown, Texas (1280, 2004), and at some locality in Mexico (2003).

Quercus Durandi, Buckley. At Sutherland Springs (1275).

Quercus stellata, Willd. At Georgetown, Texas (1281).

Quercus nigra, Linn. Same locality (1282).

Quercus coccinea, Wang. At Sutherland Springs (1283), and Georgetown, Texas (1284).

Quercus macrocarpa, Michx. At Georgetown, Texas (1285).

Quercus grisea, Liebm. In the Sierra Madre, south of Saltillo (1278), — a small tree, twenty feet high and rarely over a foot in diameter.

Quercus castanea, Nee (?), — foliage only. At Guanajuato (Dugès); 839 Parry & Palmer, a variety.

Quercus ——? Resembling forms of *Q. castanea*, but with thinner acuminate leaves, sparingly stellate-tomentose, the slender pedicel and the thin turbinate-campanulate cup hoary-tomentose. In the Sierra Madre, south of Saltillo (1277). "Red Oak"; often thirty or forty feet high.

Quercus crassifolia, Humb. & Bonpl. In the San Miguelito Mountains, San Luis Potosi (897 Schaffner); 836 Parry & Palmer.

Quercus reticulata, Humb. & Bonpl. (?), — foliage only. Mountains near San Luis Potosi (896, 898 Schaffner), and at Guanajuato (Dugès). Some of the leaves are over a foot long and 8 inches wide.

Quercus tomentosa, Willd. (?), — foliage only. Mountains near San Luis Potosi (899 Schaffner).

Quercus confertifolia, Humb. & Bonpl. In the Santa Rosa Mountains, Guanajuato (Dugès).

Salix Bonplandiana, HBK. In the mountains east of Saltillo (1286), and about San Luis Potosi (895 Schaffner).

Salix taxifolia, HBK. At Morales, San Luis Potosi (893 Schaffner); 840 Parry & Palmer.

Salix ——? In the San Miguelito Mountains, San Luis Potosi (894 Schaffner). A well-marked and apparently very distinct species. Hoary-tomentose, the leaves glabrate above, narrowly lanceolate, acute, cuneate at base, irregularly and rather bluntly serrulate, 2 to 4 inches long; petioles 2 to 4 lines long: pistillate aments appearing after the leaves, sessile, dense, very short (6 lines long or less); bracts very densely villous: ovary glabrous or nearly so.

Populus alba, Linn.; a variety with ovate-orbicular or subreniform-ovate leaves, sparingly sinuate or entire. At San Luis Potosi, in cultivated grounds (892 Schaffner); 842½ Parry & Palmer. 842 Parry & Palmer is *P. nigra*, Linn.

POPULUS FREMONTI, Watson, var. (?) WISLIZENI, Watson. In cultivated places about San Luis Potosi (891 Schaffner); 843 Parry & Palmer. One of the several forms that are provisionally referred to this species.

CERATOPHYLLUM DEMERSUM, Linn. At San Lorenzo de Laguna, Coahuila (1287).

EPHEDRA PEDUNCULATA, Engelm. Ms. A strongly marked and very distinct species, the slender elongated stems 6 to 10 feet long and climbing over surrounding bushes: leaves and fruit-scales in pairs, the latter more or less connate and becoming at length fleshy and forming a red edible pedunculate fruit: seed in pairs: anthers 5 to 7, stipitate. — At Uvalde, Texas (1291), at Saltillo (1289) and Juraz, Coahuila (1290), and at San Luis Potosi (Schaffner); 855 Parry & Palmer.

EPHEDRA ANTISYPHILITICA, Meyer. At Sutherland Springs, Texas (1292). This species has been variously confused with the last and with *E. Nevadensis*, owing to the very imperfect state of Berlandier's original specimens and the difficulty of finding characters by which to identify them. An examination of the single spike (staminate) on his specimens in the Gray herbarium shows satisfactorily that they are distinct from *E. pedunculata*, while the locality in which they were found (McMullen County, Texas) makes it certain that they cannot be the same as *E. Nevadensis*, which is not known to occur either in Texas or New Mexico. The common species of Western Texas, with which it may be considered as identical, is a rather stout and rigid bush, with opposite leaves and scales, the latter more or less connate but becoming less fleshy than in the last, and the spike more shortly pedunculate or subsessile: seed solitary: anthers 4 or 5, sessile.

EPHEDRA ASPERA, Engelm. Ms. Distinguished from the last by the very rough branches, the fruit-scales all distinct and probably not becoming fleshy, and the seed in pairs. — In the Sierra Madre, south of Saltillo, Coahuila (1288). Collected also by Gregg (53) west of Cartamullo.

CUPRESSUS ARIZONICA, Greene. In the Sierra Madre, south of Saltillo (1293). 848 Parry & Palmer appears to be the same, but with more prominent and curved bosses upon the cones, as in *C. Benthami*, from which it differs only in its more glaucous foliage. It is doubtful whether the two species are distinct.

CUPRESSUS BENTHAMI, Endl. Staminate specimens from the same region (1294), referred by Hemsley to *Juniperus flaccida*, but agreeing in every respect with this species.

JUNIPERUS FLACCIDA, Schlecht. From the same region (1295, referred to *J. tetragona*), and in the San Miguelito Mountains, San Luis Potosi (905 Schaffner); 853 Parry & Palmer.

JUNIPERUS MEXICANA, Schiede (as determined by Engelmann). In the Sierra Madre, south of Saltillo (1296).

JUNIPERUS OCCIDENTALIS, Hook., var. CONJUNGENS, Engelm. At Georgetown, Texas (1297).

TAXODIUM DISTICHUM, Rich. At Uvalde, Texas (1298).

TAXODIUM MUCRONATUM, Ten. At Santa Ana Pacueco, Guanajuato (Dugès).

PINUS LATISQUAMA, Engelm. in Gard. Chron. 2. 18. 712, fig. 125. Bark reddish brown, scaly, ½ inch thick or less, on the younger branches smooth and thin; branchlets very slender: leaves in threes, very slender, 2 to 4 inches long, entire, with short triangular bracts and close thin caducous sheaths (3 lines long): cones peduncled and subterminal, subcylindrical-ovate, about 3 inches long; scales chestnut-brown and shining, obliquely rhombic, transversely carinate, with depressed umbo and a short stout closely inflexed prickle, the middle scales 8 to 12 lines broad, the lower becoming strongly tuberculate and reflexed: seeds wingless, 6 to 8 lines long. — Dr. Engelmann's description and figure of the foliage appear to have been, through some mistake in the specimens sent to him, from that of the next species. In the Sierra Madre, south of Saltillo (1299), seen only in a single locality, on each side of a long mountain pass. Not very tall, with numerous rather slender branches.

PINUS AYACAHUITE, Ehrenb. (*P. strobiformis*, Engelm. in Wisliz. Rep. 102.) From the same region; a large tree; wood soft and easily worked. "White Pine"; "Acanita."

PINUS CEMBROIDES, Zucc. From the same region, and from the mountains east of Saltillo, the dwarf pine or piñon of the cañons; 846 Parry & Palmer.

PINUS MONTEZUMÆ, Lamb. From the Caracol Mountains, southeast of Monclova, Coahuila.

PINUS TEOCOTE, Cham. & Schlecht. (?) In the Sierra Madre, south of Saltillo; 844, 844½ Parry & Palmer. "Pino real"; "Red Pine." A tall, large, and straight tree, with very firm and compact bark, the timber solid and very durable.

ABIES RELIGIOSA, Schlecht. In the same region. "Huallame." Fine timber for carpenters' uses.

PSEUDOTSUGA DOUGLASII, Engelm. From the same region; known as "Hallarin."

MICROSTYLIS FASTIGIATA, Reichenb. f. (?) Sepals and petals thin: lip broadly ovate and somewhat auricled, shortly acuminate, deeply concave and with a shallow pit on each side of the thickened midvein. — In the Caracol Mountains, Coahuila (1300). The same as 914 Ghiesbreght.

MICROSTYLIS MONTANA, Rothr. In the San Miguelito Mountains, San Luis Potosi (517 Schaffner); 858 Parry & Palmer. This may be the same as *Malaxis elliptica*, Rich. & Gal.

HEXALECTRIS APHYLLA, Raf. (*Bletia aphylla*, Nutt.) In the Sierra Madre, south of Saltillo (2006), and in the San Miguelito Mountains (316 Schaffner); 861 Parry & Palmer.

BLETIA CAMPANULATA, Llave (?). In the San Miguelito Mountains (518 Schaffner), and at Guanajuato (Dugès). The same as 905 Ghiesbreght.

CRANICHIS SCHAFFNERI, Reichenb. f. In the San Miguelito Mountains (507 Schaffner).

SPEIRANTHES CINNABARINA, Benth. & Hook. (*Stenorhynchus cinnabarinus*, Lindl.) In the Caracol Mountains, Coahuila (Palmer), and at Guanajuato (Dugès).

SPEIRANTHES AURANTIACA, Benth. & Hook. (*Stenorhynchus aurantiacus*, Lindl.) At Guanajuato (Dugès).

SPEIRANTHES ——? In the San Miguelito Mountains (511 Schaffner.)

SPEIRANTHES ——? In the Morales Mountains, San Luis Potosi (512 Schaffner).

SPEIRANTHES ——? In the Alvarez Mountains, San Luis Potosi (513 Schaffner).

SPEIRANTHES ——? In the Hoorez Mountains, San Luis Potosi (514 Schaffner); 857 Parry & Palmer. All these are well-marked and, so far as appears, undescribed species.

HABENARIA VOLCANICA (?) (*Platanthera volcanica*, Lindl.) In the Sierra Madre, south of Saltillo (Palmer).

HABENARIA ——? In the San Miguelito Mountains (508 Schaffner); 860 Parry & Palmer.

CYPRIPEDIUM MOLLE, Lindl. At Guanajuato (Dugès).

HECHTIA GLOMERATA, Zucc. Near Morales, San Luis Potosi (501 Schaffner); 877 Parry & Palmer. The staminate inflorescence is branched and less pubescent than the fertile.

TILLANDSIA RECURVATA, Linn. At San Luis Potosi, growing upon cactus (530 Schaffner), and at Guanajuato (Dugès); 872½ Parry & Palmer. Dugès gives the popular names "Heno" and "Pastle."

IRIS MISSOURIENSIS, Nutt. At Lerios, in the high mountains east of Saltillo (1302).

IRIS FLORENTINA, Linn. In the same region (2009). Unlike any native North American species, and probably cultivated.

TIGRIDIA VANHOUTTEI, Roezl. At Guanajuato (Dugès). Known as "Jahuique"; bulbs eatable, with the taste of chestnuts. The same as 79 and 628 Ghiesbreght.

NEMASTYLIS TENUIS, Benth. & Hook. (*Chlamydostylis tenuis*, Baker.) At Guajuco, Nuevo Leon (2008). Flowers indigo-blue.

NEMASTYLIS MULTIFLORA, Benth. & Hook. (*Chlamydostylis multiflorus*, Baker.) At Morales, San Luis Potosi (538 Schaffner); Parry & Palmer, without number. This is probably Baker's species in part. The flowers are larger than described by him, the perianth being 12 to 14 lines long, and the column of filaments nearly half an inch long. The capsules are oblong, 8 lines long; seeds obliquely oblong-ovate, finely tuberculate; connective as broad as the anther-cells.

NEMASTYLIS NANA. Bulb small, with dark brown coats: leaves very narrow, 3 to 6 inches long: scape an inch or two long, bearing a single elongated leaf and one or two peduncles; spathes 9 lines long, the outer valve shorter and acuminate, the inner acute and closely convolute, 1-flowered; pedicel included: perianth greenish white, the nearly equal segments 4 to 7 lines long: stamineal tube a line long, the anthers with very narrow connective, 3 lines long: styles half as long, very slender, ascending: capsule oblong-ovate, 3 lines long.— In the Escabrillos Mountains, San Luis Potosi (539 Schaffner); 887 Parry & Palmer.

SISYRINCHIUM TENUIFOLIUM, Humb. & Bonpl. At Lerios, Coahuila (1301), and near Morales, San Luis Potosi (528 Schaffner); 878 and 880 Parry & Palmer, and 523 and 2664 Bourgeau. It is the same also as 231 Hartweg, which is probably the type of *S. Hartwegi*, Baker, of which the name only appears to have been published, without description or other means of identification.

SISYRINCHIUM SCABRUM, Cham. & Schlecht. At Lerios, Coahuila (2007), near Morales (529 Schaffner), and at Guanajuato (Dugès). Differing little, except in its scabrous margins, from *S. anceps*, Cav., which also occurs in Mexico (Gregg; 222 Hartweg; 879 and 879½ Parry & Palmer).

SISYRINCHIUM SCHAFFNERI. Root of slender fibres: scape simple, 1 to 4 inches high, equalling or exceeding the rather broad leaves (½ to over 1 line wide); margins distantly serrulate: spathe 2–6-flowered, the inner valve about 6 lines long, the outer usually longer: flowers yellow, the acute segments 3 lines long: capsule oblong-obovate, more or less narrowed at base, 2 or 3 lines long. — At San Luis Potosi (527 Schaffner); 881 Parry & Palmer.

HYPOXIS DECUMBENS, Linn. At San Luis Potosi (545 Schaffner); 871 Parry & Palmer. Collected by Mr. Lemmon in the Huachuca Mountains, Arizona.

COOPERIA DRUMMONDII, Herb. At Laredo, Texas (1304).

ZEPHYRANTHES TEXANA, Herb. (*Hippeastrum Texanum*, Baker.) At San Antonio, Texas (1305).

ZEPHYRANTHES CONCOLOR, Benth. & Hook. (*Hippeastrum concolor*, Baker.) At Morales, San Luis Potosi (540^b Schaffner); 868 Parry & Palmer.

ZEPHYRANTHES PALLIDA, Roem. At San Luis Potosi (541 Schaffner); 869 Parry & Palmer.

ZEPHYRANTHES CARINATA, Herb. At Guanajuato (Dugès). Known as "Mayo."

ZEPHYRANTHES AUREA. Distinguished from *Z. Texana* by the shorter and stouter peduncle (rarely over ½ inch long), the yellow perianth of the same color outside or usually greenish, the capsule much larger (6 lines long), and the larger seeds (3 lines long). — From Texas to Arizona and Mexico. At Laredo, on the Rio Grande (1303), and at San Luis Potosi (540 Schaffner); 870 Parry & Palmer. Collected also at Fort Davis, Texas, by Dr. J. B. Girard; in New Mexico by Wright (1904), and near Silver City by E. L. Greene; in Arizona, near Fort Huachuca, by J. G. Lemmon; and in Mexico by Gregg (491).

BOMARIA ACUTIFOLIA, Herb. At Guanajuato (Dugès).

BRAVOA GEMINIFLORA, Llav. & Lex. Same locality (Dugès).

BESCHORNERIA TUBIFLORA, Kunth. In the Morales Mountains, San Luis Potosi (504 Schaffner); 866 Parry & Palmer.

AGAVE MACULOSA, Hook. At Guadalupe, Texas (1306).

AGAVE GUTTATA, Jac. & Bouché. In the Morales Mountains (505 Schaffner); 865 Parry & Palmer. The specimens accord with the description given by Baker (Gard. Chron. 2. 8. 808), except that the leaves are distinctly serrulate and the flowers smaller (less than an inch long, the filaments an inch long). Known as "Lechuguilla."

AGAVE VARIEGATA, Jacobi. In the San Miguelito Mountains (506 Schaffner). Filaments (about 15 lines long) scarcely more than half as long as described and figured, and the leaves even more distinctly serrulate than in the last. Also known as "Lechuguilla."

Agave revoluta, Klotzsch (?) At Saltillo, Coahuila (1307). Much resembling the last, but the leaves more undulate and not at all serrulate, and the tube of the perianth somewhat longer and narrower.

Agave asperrima, Jacobi. Acaulescent: leaves few, narrowly oblanceolate and long-acuminate, 2 feet long by 3 or 4 inches wide, channelled, glaucous and rough, terminating in a slightly decurrent brown slender spine 1½ to 3 inches long, and with broad brown spines upon the fleshy margin, 4 to 8 lines long, reflexed and often variously curved: flowers numerous, panicled; ovary linear, 9 lines long; perianth-tube 6 lines long, with the stamens inserted on the middle; segments 10 lines long: filaments about 2 inches long: capsule sessile, oblong, 1½ to 2 inches long: seeds smooth, 3 lines long. — At San Lorenzo de Laguna, Coahuila (1309), and in cultivation at Cambridge. Of the *A. Americana* group, and remarkable for its rough glaucous leaves and very long spines. The species has been referred by Baker to *A. Salmiana*, but proves to be very distinct. Seeds have been distributed by Dr. Engelmann under the name *A. longispina.*

Agave Wislizeni, Engelm. In the Caracol Mountains, southeast of Monclova, Coahuila (1310).

Agave Americana, Linn. At Monclova, Coahuila (1313).

Agave ——— (?) Flowers only, in a large panicle: ovary an inch long or more: perianth 18 lines long above the ovary, very fleshy, the broad tube about 4 lines long, and the very stout filaments (3 inches long) adnate over two thirds of its length. — At Saltillo (1308).

Agave falcata, Engelm. Leaves numerous, a foot long, very rigid, falcate, sharply serrulate, the terminal spine 1 to 1½ inches long: flowering stem 5 feet high; flowers as described: capsule 6 lines long, deeply channelled on the sides, coarsely striate, tardily dehiscent: seeds 1½ to 2 lines long. — At Parras, Coahuila (1314).

Agave bracteosa, Watson; Engelm. in Gard. Chron. 2. 18. 776, figs. 138, 139. Acaulescent, with narrow fleshy minutely serrulate leaves, 1½ to 2 feet long, attenuate from near the base to an herbaceous tip: flowering stem 3 feet high, covered with numerous recurved subulate-filiform bracts, 4 to 6 inches long or more: flowers in pairs in a very dense spike, subtended by short membranous bracts; ovary and perianth each 6 lines long, the latter divided very nearly to the base: filaments 2 inches long: capsules oblong, 6 lines long. — On mountain cliffs fifteen miles from Monterey, Nuevo Leon (Palmer); in cultivation at Cambridge.

AGAVE VICTORIÆ-REGINÆ, Moore. On gravel-banks in the same locality (Palmer), and in cultivation at Cambridge, where it has flowered (Gard. Chron. 2. 18. 841, fig. 149). Flowering stalk over 10 feet high, the flowers by threes in a very dense spike: perianth 9 lines long, exceeding the ovary: filaments 15 lines long, inserted on the middle of the very short tube.

DIOSCOREA ——? At Guanajuato (Dugès). A staminate specimen, with small hexandrous flowers in simple short-pedunculate racemes shorter than the cordate acuminate leaves: finely pubescent. Known as "Camote del Cerro."

DIOSCOREA ——? At Guanajuato (Dugès). Staminate specimens of a very delicate slender glabrous species, with minute greenish 3-androus flowers in short simple racemes rather exceeding the small cuspidate oblong-cordate leaves.

SMILAX BONA-NOX, Linn. (*S. tamnoides*, Gray, Manual.) A form with auriculate-lanceolate acuminate leaves, subcordate at base, 3–5-nerved. Collected by Schaffner, but the ticket lost.

YUCCA ANGUSTIFOLIA, Pursh, var. MOLLIS, Engelm.; with the narrow (2½ to 4 lines wide) and rather rigid pungent leaves of var. *elata*. At Uvalde, Texas (1312).

YUCCA RUPICOLA, Scheele, var. RIGIDA, Engelm. At Monclova, Coahuila. Flowering stem 8 to 10 feet high; leaves 15 to 18 inches long by 4 or 5 lines broad, scarcely pungent: capsules 2 to 2½ inches long, acuminate, the valves not splitting at the apex: seeds 3 lines broad. Known as "Amole."

NOLINA LINDHEIMERIANA, Watson. At Sutherland Springs (1316).

NOLINA HUMILIS, Watson. Near San Miguelito, San Luis Potosi (502 Schaffner); 875 Parry & Palmer. Palmer also collected in the Sierra Madre, south of Saltillo, a staminate specimen with the flowering stem and inflorescence (a foot high) coarsely rough-pubescent, the bracts narrower at base, longer and more attenuate, and the leaves more or less rough on the back. This may be the same as 874 Parry & Palmer (the specimen in the Gray herbarium insufficient for determination), which Mr. Baker has separated under the name *Beaucarnea Watsoni*.

DASYLIRION GLAUCOPHYLLUM, Hook. (?) A fruiting specimen not positively referable to any of the described species. Leaves 4 feet long, somewhat glaucous at base, the margins between the teeth only very minutely serrulate, and the thin extremity not splitting into threads but dying and breaking off; base 2½ inches wide: flowering stem 10 feet high, the numerous crowded erect panicles shorter than the broad conspicuous bracts (mostly 3 inches long): fruit closely resembling that of *D. Wheeleri.* — At Monclova, Coahuila.

DASYLIRION ACROTRICHUM, Zucc. At San Luis Potosi (500 Schaffner); 876 Parry & Palmer. Referred by me (Proc. Amer. Acad. 14. 249) to *D. graminifolium*, Zucc., but Mr. Baker is probably more correct in considering it a form of *D. acrotrichum.* Known as "Cucharilla."

ANTHERICUM STENOCARPUM, Baker. (*Hesperanthes stenocarpa*, Watson.) At Lerios, Coahuila (2012).

ANTHERICUM LEPTOPHYLLUM, Baker. (*Hesperanthes leptophylla*, Watson.) In the San Miguelito Mountains, San Luis Potosi (543 Schaffner); 890 Parry & Palmer, in part. Mr. Bentham's judgment is yielded to in retaining these species in *Anthericum.*

ECHEANDIA TERNIFLORA, Ort. At Guanajuato (Dugès); 890 Parry & Palmer, in part.

GLYPHOSPERMA* PALMERI. Glabrous: stem 1 or 2 feet high, usually sparingly branched: leaves membranously sheathing at base, 6 to 10 inches long: racemes loose; pedicels erect, 2 or 3 lines long: perianth-segments oblong, obtuse, 4 or 5 lines long, with a broad brown midnerve: outer filaments a half shorter than the inner and with a somewhat more dilated base: stigmas salmon-colored: capsule 2 lines long: seeds with 3 or 4 furrows on the back and usually 3 pits on each side. — In sandy valleys at Saltillo, Coahuila (1320), and in cultivation at Cambridge.

HEMIPHYLACUS* LATIFOLIUS. Tuberous roots dilated downward, 6 inches long or more; caudex covered with the fibro-membranous bases of old leaves: leaves thin, nearly a foot long, 8 to 12 lines broad: stem sparingly branched, 2 feet high: racemes elongated,

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* The following new genera are proposed. The first, belonging to Bentham's subtribe *Anthericeæ*, is remarkable for the large colored stigmas, the peculiar filaments, the short dorsifixed anthers, the 1-nerved perianth-segments, the pitted rugose seeds, and the terete fistulous leaves. The second, intermediate between the *Chlorogaleæ* and the *Anthericeæ*, is characterized especially by the adnate filaments, only the inner and shorter ones antheriferous, and the scarious 1-nerved perianth-segments, in connection with the tuberous roots.

GLYPHOSPERMA. Perianth-segments distinct, spreading, 1-nerved, at length connivent and soon deciduous, not twisted. Stamens 6, shorter than the perianth, upon its base: filaments clavate above a dilated pubescent base, the inner three longest: anthers versatile, short-oblong, introrse. Ovary sessile, globose: style shorter than the stamens, deciduous; stigmas 3, obovate, colored: ovules 2 in each cell, pendulous. Capsule thin-coriaceous, obovate, subtriquetrous, 3-celled, loculicidal. Seeds 1 or 2 in each cell, triquetrous, dark ash-color, strongly rugose across the back, pitted on the sides: embryo in fleshy albumen, secund; pedicels solitary, 2 to 4 lines long, about equalling the lanceolate acuminate bracts, at length spreading or recurved: perianth-segments lanceolate, 4 lines long, the midnerve not colored: sterile filaments scarcely shorter than the perianth, all adnate to its middle: style a line long, at length declinate: capsule very shortly stipitate, 2 to 3 lines long and broad.—In the mountains six miles east of Saltillo, Coahuila (1319).

MILLA BIFLORA, Cav. At San Luis Potosi (Schaffner); 884 Parry & Palmer.

NOTHOSCORDUM STRIATUM, Kunth. At Guadalupe, Texas (2009), at Lerios (1317) and Monclova, Coahuila, at Guajuco, Nuevo Leon (1318), and at San Luis Potosi (537ª Schaffner); 886 Parry & Palmer.

ALLIUM SCAPOSUM, Benth. In the San Miguelito Mountains, San Luis Potosi (537ᵇ Schaffner), and at Guanajuato (Dugès); 885 Parry & Palmer, at least in part. It is doubtful if *A. glandulosum*, Link & Otto, be not the same with deeper colored flowers, as represented by 885 Parry & Palmer, in part, and 1567 Coulter. Specimens collected by Dr. Palmer at Soledad, Coahuila (2010), are perhaps a stout form of *A. scaposum*, with more numerous and shorter pedicels (6 lines long), and light pink flowers. *A. longifolium*, Spreng. (*Schœnoprasum longifolium*, HBK.), is probably *Nothoscordum striatum*.

CALOCHORTUS FLAVUS, Schult. f. In the San Miguelito Mountains (542 Schaffner), and at Guanajuato (Dugès); 891 Parry & Palmer.

ZYGADENUS VOLCANICUS, Benth. In the San Miguelito Mountains (544 Schaffner); 892 Parry & Palmer.

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nearly as long, slightly curved.—Root fleshy-fibrous. Leaves radical, terete or slightly concave on the inner side, fistulous. Stem branching, leafless, with scarious bracts at the nodes. Inflorescence racemose, the pedicels solitary, jointed in the middle. Flowers small, light salmon-color.

HEMIPHYLACUS. Perianth persistent, the distinct equal spreading 1-nerved segments at length lax and scarious. Stamens perigynous, included; filaments slender, naked, unequal, adnate to the middle, those upon the outer segments longest and without anthers; anthers versatile, rounded, introrse. Ovary nearly sessile, 3-celled, 3-lobed: style slender, persistent; stigmas minute: ovules 3 to 6 in each cell, upon the middle of the axis. Capsule coriaceous, broadly triquetrous-ovate, loculicidal. Seeds 1 or 2 in each cell, black. Embryo slightly curved, in fleshy albumen.—A glabrous perennial, with long tuberous fascicled roots. Leaves radical, very broadly linear. Stem naked, branched above, with scarious bracts. Flowers small, in loose racemes, white or yellowish; pedicels jointed at the summit.

Zygadenus porrifolius, Greene. In the Sierra Madre, south of Saltillo (1321).

Schœnocaulon Drummondii, Gray. At Sutherland Springs, Texas (1322), and in the San Miguelito Mountains (536 Schaffner), where it is known as "Matu Curros"; 882 Parry & Palmer; 1570 Coulter. The Mexican specimens scarcely differ from the Texan, — the stamens usually rather shorter, and capsules somewhat more obtuse at each end.

Heteranthera limosa, Vahl. At Guadalupe, Texas (1323), at Morales (519 Schaffner) and near Ladrillera, San Luis Potosi (Schaffner); 899 Parry & Palmer.

Heteranthera reniformis, Ruiz & Pavon. Near Morales (520 Schaffner), and at Guanajuato (Dugès); 898 Parry & Palmer.

Heteranthera Mexicana. Stems short, ascending from a short rooting base, somewhat glandular-pubescent above with the inflorescence: leaves linear with a dilated sheathing base, 3 or 4 inches long by 1 or 2 lines broad: spathe ovate-lanceolate, acuminate, 9 lines long: spike pedunculate above the spathe, 2 to 4 inches long, 12–15-flowered, naked, the flowers scattered, ascending: perianth-tube 3 or 4 lines long, greenish, pubescent, the limb as long, spreading, blue with white centre: one stamen nearly twice longer than the others and equalling the style: capsule oblong-ovate, 2 or 3 lines long: seeds nearly globose, 12-striate. — Closely resembling *H. Seubertiana.* At Juraz, on the Sabinas River, Coahuila (1324).

Commelina pallida, Willd. In the Sierra Madre, south of Saltillo (1326), and at Guanajuato (Dugès), where it is called "Yerba del Pollo."

Commelina Virginica, Linn. At Uvalde, Texas (2015).

Commelina graminifolia, HBK. At San Luis Potosi (526 Schaffner); 903 Parry & Palmer.

Tinantia fugax, Scheidw. At Guanajuato (Dugès).

Tradescantia Karwinskyana, Roem. & Schult. In the Sierra Madre, south of Saltillo (1325), and at San Luis Potosi (525 Schaffner); 900 Parry & Palmer.

Tradescantia crassifolia, Cav., var. (?) angustifolia. Low (a foot high or less): leaves linear to linear-lanceolate: umbels loosely few-flowered: sepals less than 3 lines long, villous or glandular-pubescent: ovary hairy only at the summit. — In the Sierra Madre, south of Saltillo (2016), and in the Morales Mountains (521 Schaffner); 253 Gregg. The typical form was collected by Schaffner (523) in the San Miguelito Mountains; 902 Parry & Palmer.

TRADESCANTIA LEIANDRA, Torr. (*Zebrina* (?) *leiandra*, C. B. Clarke in A. DC. Monogr. 3. 318.) At Soledad, Coahuila (2014). Cells 2-seeded, or the dorsal cell 1-seeded. Referred doubtfully by Clarke to *Zebrina*, but it has none of the characteristics of that genus, and in no respect differs from *Tradescantia*. 700 Wright, as found in Herb. Gray, includes not only this species, but a specimen of *Commelina Virginica*, and another of *Commelina dianthifolia* (as noted by Mr. Clarke under that species, though it is also described by him as *C. leiandra*).

TRADESCANTIA LINEARIS, Benth. In the San Miguelito Mountains (524 Schaffner); 901 Parry & Palmer, referred by Clarke to *T. venustula*, Kunth. Collected also by Dr. Edwards at Rinconada. Distinguished especially from *T. venustula* by the broader fleshy connective. 701 Wright, referred by Dr. Torrey doubtfully to *T. rosea* and by Mr. Clarke to this species, is distinct from both, — possibly a dwarf small-flowered *T. Virginica*, or glabrous *T. tuberosa*.

CALLISIA INSIGNIS, Clarke. Near Morales, San Luis Potosi (522 Schaffner).*

JUNCUS BALTICUS, Willd. At San Luis Potosi (554 Schaffner).

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* The genera and species of the order *Commelinaceæ* in the United States, studied with reference to the revision of the order by Mr. C. B. Clarke in De-Candolle's *Monographiæ*, are as follows: —

COMMELINA, Dill. Cyme sessile within a cordate or connate bract (spathe). Perfect stamens 3. Cells of the capsule 1- or 2-seeded.

* Ventral cells 2-ovuled (and usually 2-seeded), the dorsal 1-ovuled.

+ Margins of the spathe not united.

1. C. NUDIFLORA, Linn. (*C. Cayennensis*, Rich. *C. communis*, of Chapman.) Slender and creeping: leaves lanceolate: spathe cordate, acute: seeds reticulated. — From Delaware to Florida, and Missouri to Texas.

2. C. DIANTHIFOLIA, DC. (*C. linearis*, Benth. *C. leiandra*, Clarke.) Slender, erect, from a tuberous root: leaves linear: spathe cordate and long-attenuate: seeds wrinkled or pitted. — Northwestern Texas to New Mexico and Mexico.

+ + Margins of the spathe united.

3. C. HIRTELLA, Vahl. (*C. erecta*, of Gray and Chapman.) Stout, erect: leaves large, lanceolate, the sheaths brown-bearded: spathes crowded: seeds smooth. — From Pennsylvania to Florida, and Kentucky to Texas.

* * Cells 1-ovuled, 1-seeded: seeds smooth: roots fleshy, subtuberous.

4. C. ERECTA, Linn. Slender, often low: leaves linear: cells all dehiscent. — Pennsylvania to Florida.

5. C. VIRGINICA, Linn. Slender, usually tall: leaves lanceolate to linear: dorsal cell indehiscent, scabrous. — From Southern New York to Michigan and southward to Florida, the Indian Territory, and Mexico; West Indies.

JUNCUS TENUIS, Willd. At San Miguelito (555 Schaffner); 894 Parry & Palmer.

JUNCUS BUFONIUS, Linn. At San Luis Potosi (556 Schaffner); 896 Parry & Palmer.

JUNCUS NODOSUS, Linn. At San Luis Potosi (551 Schaffner).

TRADESCANTIA, Linn. Umbel-like cyme subtended by leaf-like or small and scarious bracts. Perfect stamens 6 (or 5). Cells of the capsule 2-seeded.

* Umbel terminal, sessile, subtended by two leaf-like bracts: leaves lanceolate.

1. T. MICRANTHA, Torr. Low and rooting, slender, subpubescent: leaves an inch long or less: flowers small (2 lines long): filaments all hairy. — Southwestern Texas.

2. T. LEIANDRA, Torr. *Stout, rooting at base, a foot high: leaves* 2 or 3 inches long, somewhat villous or nearly glabrous: sepals more or less villous, 3 or 4 lines long: filaments all naked. — Western Texas and Mexico.

* * Umbels terminal or sometimes lateral, sessile, subtended by one or two leaf-like bracts: leaves linear to narrowly lanceolate.

3. T. VIRGINICA, Linn. Very variable: roots fleshy-fibrous: bracts usually a pair: the typical form smooth or only slightly villous, more or less glaucous, often tall and slender and with linear leaves, rather rarely with one or two long lateral peduncles. From the Upper Missouri and Lake Winnipeg to New York and southward, and from Texas to Southern Utah and Arizona. — Var. VILLOSA. Similar, but often dwarf, more or less villous throughout, as well as pubescent. In the Mississippi Valley and Gulf States. (Var. *Drummondii*, Clarke, is a dwarf densely pubescent form of this, not at all villous, collected by Drummond in Texas.) — Var. FLEXUOSA. (*T. flexuosa*, Raf.) Stout and dark green, with large linear-lanceolate pubescent leaves, the stem usually flexuous, and with several short lateral branches or sessile axillary heads. From Ohio to Kentucky and Georgia. The extreme forms appear very distinct, but an examination of cultivated and numerous herbarium specimens fails to show satisfactory reliable characters upon which to separate them. *T. pilosa*, Lehm., is intermediate between the last and the preceding forms.

4. T. TUBEROSA, Greene. Very slender, from tuberous roots, glandular-pubescent: leaves very narrowly linear: bracts solitary: flowers smaller (sepals 2 or 3 lines long). — New Mexico and Arizona.

* * * Umbel pedunculate, subtended by small subscarious bracts: flowers small.

5. T. ROSEA, Vent. Erect from a running rootstock: leaves very narrowly linear. — Maryland to Florida.

6. T. FLORIDANA, Watson. Prostrate and rooting: leaves oblong-ovate. — Florida.

TINANTIA, Scheidw. Cyme prolonged and scorpioid, pedunculate. Otherwise as *Tradescantia*.

1. T. ANOMALA, Clarke. (*Etheosanthes ciliata*, Raf. *Tradescantia anomala*, Torr.) Tall, glabrous: leaves cordate-ovate to cordate-lanceolate, the upper sessile: inflorescence shorter than the upper leaf; flowers few; sepals 6 lines long. — Louisiana and Texas.

JUNCUS ACUMINATUS, Michx. At San Luis Potosi (552, 553 Schaffner); 893 and 895 Parry & Palmer.

JUNCUS MARGINATUS, Rost. At Morales, San Luis Potosi (550 Schaffner).

JUNCUS XIPHIOIDES, Meyer. At Morales (549 Schaffner); 897 Parry & Palmer.

POTAMOGETON NATANS, Linn. A variety with oblong leaves acute at each end. At San Luis Potosi (535 Schaffner), and at Guanajuato (Dugès).

POTAMOGETON HYBRIDUS, Michx. Near Morales (534 Schaffner); 856 Parry & Palmer.

POTAMOGETON PAUCIFLORUS, Pursh. Also near Morales (533 Schaffner).

CYPERUS FLAVESCENS, Linn. At San Luis Potosi (569 Schaffner).

CYPERUS MELANOSTACHYUS, HBK. At San Luis Potosi (568 Schaffner); 904 Parry & Palmer.

CYPERUS FLAVICOMUS, Michx. At Guanajuato (Dugès); called "Tule." The same as 431 Bourgeau.

CYPERUS ARISTATUS, Rottb. Near Monclova, Coahuila (1330), and San Rafael, San Luis Potosi (563 Schaffner).

CYPERUS SCHWEINITZII, Torr., var., with blunter scales and shorter nutlets. Near Morales, San Luis Potosi (561 Schaffner); 907 Parry & Palmer. The same as 703 Wright, referred to this species by Dr. Torrey.

CYPERUS VIRENS, Michx. At San Miguelito, San Luis Potosi (562 Schaffner).

CYPERUS ——? Near *C. acuminatus*, Torr., but the tips of the scales less spreading and the nutlets oblong: contracted umbel sublateral (one involucral bract stouter and erect). At Morales, San Luis Potosi (564 Schaffner).

CYPERUS ——? Of the same group with the last. Perennial, with a single dense sessile head, or with one or more additional rays, the spikelets very numerous: scales very dark brown with green midnerve, long-acuminate: nutlet sharply triangular, nearly as broad as high. — At Pozos, San Luis Potosi (566 Schaffner); 905 Parry & Palmer.

CYPERUS DIVERGENS, HBK. In the San Rafael Mountains, San Luis Potosi (1032 Schaffner), and at Guanajuato (Dugès); 910, 911 and 911½ Parry & Palmer; 1612, 1623 Coulter. The same as 256 Hartweg, so named by Bentham. The scales at length become white and scarious.

CYPERUS ——? Allied to *C. filiculmis*, Torr., and *C. leucolepis*, Boeckl. (1611 Coulter), but the spikelets in loose spikes loosely umbellate. At San Luis Potosi (560 Schaffner).

CYPERUS ARTICULATUS, Linn. At Guanajuato (Dugès). Known as "Tule Chico."

CYPERUS PHYMATODES, Muhl. At San Luis Potosi (559 Schaffner), and Guanajuato (Dugès); 908 Parry & Palmer; 254 Hartweg.

CYPERUS ——? Very near *C. erythrorrhizos*, Michx., but the nutlet elliptical and a half longer. At Guanajuato (Dugès). Known as "Tule grande."

CYPERUS BALDWINII, Torr. At Guadalupe (1331) and Bluffton, Texas (1332).

CYPERUS UNIFLORUS, Torr. West of San Antonio, Texas (2018).

CYPERUS INCOMPLETUS, Link. At Guanajuato (Dugès). Apparently according with the description.

CYPERUS OVULARIS, Torr. West of San Antonio, Texas (2017).

CYPERUS FLAVUS, Vahl. At San Miguelito, San Luis Potosi (565 Schaffner); 909 Parry & Palmer.

CYPERUS MICHAUXIANUS, Schultes. At Sutherland Springs (1333), and at Uvalde, Texas (1334), the latter a stout highly developed form, with the umbel a foot long and the involucral leaves nearly 3 feet in length.

ELEOCHARIS CAPITATA, R. Brown. At Sutherland Springs, Texas (1328). The same as 711 Wright, which is referred to *E. albida* in herb. Torrey.

ELEOCHARIS PALUSTRIS, R. Brown. At San Luis Potosi (576 Schaffner); 913 Parry & Palmer.

ELEOCHARIS ARENICOLA, Torr. Near Morales (577 Schaffner) and at Penasco, San Luis Potosi (578 Schaffner).

ELEOCHARIS ——? Resembling *E. microcarpa*, Torr., but the greenish nutlet somewhat larger and more turgid, minutely striate longitudinally; bristles as long as the nutlet. Near Morales, San Luis Potosi (575 Schaffner, in part).

ELEOCHARIS CANCELLATA. Of the same group and habit as the last, the angular scapes 1 to 1½ inches high and the greenish spikes 1 to 1½ lines long: scales short, obtuse, with a narrow brown line on each side: nutlet without bristles, obovate-pyriform, white and shining, minutely cancellate, the narrow meshes of the reticulation transverse and in vertical lines: tubercle much depressed. — Near *E. Liebmanniana*, Boeck. With the last (575 Schaffner, in part); 912 Parry & Palmer.

ELEOCHARIS ACICULARIS, R. Brown. At San Luis Potosi (574 Schaffner); 914 Parry & Palmer.

DICROMENA LEUCOCEPHALA, Michx. At Sutherland Springs, Texas (1329).

FIMBRISTYLIS AUTUMNALIS, Roem. & Schult. At same locality (1327).

FIMBRISTYLIS CAPILLARIS, Gray. At San Luis Potosi (557 Schaffner); 915, 916 Parry & Palmer.

FIMBRISTYLIS ——? Apparently undescribed. Culm flattened, 6 inches high or more, rough-edged above: leaves very rough on the margin, 1 or 2 lines wide: spikelets somewhat clustered in a loose compound umbel, narrow and rather few-flowered, 2 or 3 lines long; scales brown: nutlet triquetrous, white, smooth. — In the San Miguelito Mountains (558 Schaffner).

SCIRPUS SUPINUS, Linn. At Penasco, San Luis Potosi (571 Schaffner).

SCIRPUS ——? Very near *S. riparius*, Spreng. (*S. pygmæus*, Gray), but the nutlets somewhat rugulose transversely. At San Luis Potosi (572 Schaffner).

SCIRPUS HETEROCARPUS. Roots fibrous: culms and leaves filiform, 1 to 3 inches long: spikes narrow, 2 to 4 lines long, solitary and naked upon the culm, and also sessile at the base of the leaves; basal spikes few-flowered, or flowers sometimes solitary in the axils of the leaves: scales of the terminal spike lanceolate, acuminate, chestnut-colored, the lowest often elongated and bract-like, the upper ones sterile and mostly only staminate: stamens 2; bristles none: style trifid; nutlet triangular-obovate, with a short blunt beak, white, obscurely rugulose, those in the basal spikes very much larger (½ line long or more). — At Penasco, San Luis Potosi (573 Schaffner), and collected also at Orizaba by Botteri (778 in herb. Gray). A very curious species, remarkable for the numerous basal spikes, which seem to be a constant characteristic, the dimorphous nutlets, and the partially staminate terminal spikes.

FUIRENA SQUARROSA, Michx. At Sutherland Springs, Texas (1335), and at Monclova, Coahuila (1336). — Also var. PUMILA, Torr., at San Rafael, San Luis Potosi (567 Schaffner).

HEMICARPHA SUBSQUARROSA, Nees. At San Luis Potosi (570 Schaffner).

RHYNCHOSPORA ——? Perhaps a reduced form of *R. Schaffneri*, Boeckl. In the San Rafael Mountains (548 Schaffner); 918 Parry & Palmer.

Carex Schaffneri, W. Boott; *new sp.* Rootstock creeping, branching, clothed with imbricate brown scales that become fibrous: culm about a foot high, slender, scabrous above on the sharp angles: leaves about equalling the culm, 1 line broad, attenuate to a long filiform apex, flat or conduplicate above: spike about an inch long, of 3 or more oblong sessile clusters of lanceolate androgynous spikelets, the upper clusters crowded, the lowest distinct and rarely borne on a long radical peduncle; spikelets 5 or 6 lines long, male above: bracts filiform from an ovate several-nerved green-keeled hyaline-margined clasping base, the lowest much longer than the culm and the next one or two often exceeding it: scales hyaline, pale-chestnut with a green keel, ovate, acute or roughly awn-pointed, exceeding the perigynia, which are pale brown, ovate or lanceolate, 2 lines long, tapering at base, covered with irregular yellowish somewhat scurfy tubercles, obliquely cut at the top and ending in 2 long subulate rough teeth, serrate on the green margins: stamens 3: stigmas 2, long. (*W. Boott.*) — At San Luis Potosi (546 Schaffner).

Carex ——? Very near *C. varia*, Muhl., but differing in its stoloniferous rootstock, in its large male spike (an inch long), in the staminate summits of the female spikes, and in the larger and more numerously nerved perigynium, which is much less contracted at both ends. (*W. Boott.*) — At San Luis Potosi (547 Schaffner); 917 Parry & Palmer.

Paspalum distichum, Linn. At San Luis Potosi (1071 Schaffner). Known as "Grama."

Paspalum Humboldtianum, Fluegge. At San Luis Potosi (1053 Schaffner).

Panicum leucophæum, HBK. (*P. lacnanthum*, Torr.) Collected by Palmer (1341) but the locality uncertain, and near Morales, San Luis Potosi (1064 Schaffner).

Panicum Crus-galli, Linn., var. echinatum, Doell. At Uvalde, Texas (1340).

Panicum colonum, Linn. At Morales (1038 Schaffner).

Panicum obtusum, HBK. At San Luis Potosi (1039 Schaffner); 960 Parry & Palmer.

Panicum dichotomum, Linn., var. (*P. nitidum*, Lam.) At San Luis Potosi (1036, 1037 Schaffner).

Panicum repens, Linn. (*P. arenarium*, Brot.) At San Luis Potosi (1040 Schaffner).

Panicum cæspitosum, Swartz, ex Fourn., as named at Kew. Morales, San Luis Potosi (1080 Schaffner); 962 Parry & Palmer.

Panicum divaricatum, Linn. At Guanajuato (Dugès); "Otatillo pequeño." In fruit, and usually with one or more of the glumes black.

Panicum ——? A slender erect yellowish annual, many-stemmed, a foot or two high, with small acuminate spikelets in loose narrow panicles. It is the same as n. 286 of Drummond's second Texan collection, and is referred by Dr. Vasey to *P. giganteum*, Scheele, which however is probably only a form of *P. agrostoides.* — In the mountains west of Saltillo, Coahuila (1338).

Oplismenus setarius, Roem. & Schult. At Georgetown, Texas (1339). Common in the Southern States, and usually referred to *O. hirtellus* (*Panicum hirtellum*, Linn.).

Setaria imberbis, Roem. & Schult. At Parras, Coahuila (1363), and at San Luis Potosi (1042, and 1043 in part, Schaffner).

Setaria glauca, Beauv. At San Luis Potosi (1041 Schaffner).

Setaria uniseta, Fourn., as named at Kew. (*Urochloa uniseta,* Presl. *Panicum unisetum*, Trin.) At San Luis Potosi (1043 Schaffner, in part); 957 Parry & Palmer. Also a dwarf form, 1 to 3 inches high; in the San Miguelito Mountains (1044 Schaffner).

Cenchrus tribuloides, Linn. At Guadalupe, Texas (1342), and at San Luis Potosi (1046 Schaffner).

Cenchrus echinatus, Linn. At Monclova, Coahuila (1343).

Coix arundinacea, Lam. (?) At Saltillo (1337). Tall and stout, probably perennial: fruit globose-ovate, as broad as long. Cultivated in the Botanic Garden at Cambridge, it had reached a height of 8 or 10 feet when it was cut down by the frost.

Ægopogon cenchroides, Humb. & Bonpl. At San Luis Potosi (1060 Schaffner); 942 Parry & Palmer.

Tragus racemosus, Desf. At Soledad, Coahuila (1344), and at San Luis Potosi (1047 Schaffner); 952 Parry & Palmer.

Schaffnera gracilis, Benth. in Hook. Icon. t. 1378. In the San Miguelito Mountains (1070 Schaffner).

Trachypogon Montufari, Nees. At San Luis Potosi (1063 Schaffner); 964 Parry & Palmer.

Heteropogon contortus, Roem. & Schult. At Monclova, Coahuila (1346), and at Morales, San Luis Potosi (1051 Schaffner); 955 Parry & Palmer.

Andropogon laguroides, DC. At Monclova, Coahuila (1347); the same as 233 and 2969 Bourgeau (so named by Fournier), and 667 Botteri. It was collected in Texas by Berlandier (444 and 1764), and recently by Pringle in Arizona (distributed as *A. Torreyanus*).

ANDROPOGON VIRGINICUS, Linn. At San Luis Potosi (1049 Schaffner).

ANDROPOGON MYOSURUS, Presl (?) At San Luis Potosi (1050 Schaffner).

ANDROPOGON HIRTIFLORUS, Kunth. Same locality (1050 Schaffner); 966 Parry & Palmer, and the same as 752 Bourgeau.

ANDROPOGON LEUCOPOGON, Nees. Same locality (1056 Schaffner).

ARISTIDA PURPUREA, Nutt., var. BERLANDIERI, Trin. & Rupr. At Guadalupe, Texas (1350).

ARISTIDA BROMOIDES, HBK. At Parras (1352, a large form), and in the mountains west of Saltillo (1351, an erect form); also at San Luis Potosi (1066 Schaffner).

ARISTIDA DIVARICATA, Humb. & Bonpl. At San Luis Potosi (1057 Schaffner).

STIPA VIRIDULA, Trin. At Lerios, Coahuila (1249). Dr. Palmer notes that this grass is considered poisonous to animals, having a temporary narcotic effect upon them.

STIPA JURAVA, Beauv. (*S. eriostachya*, HBK., Nov. Gen. 1. 127, t. 41.) At San Luis Potosi (1054 Schaffner).

STIPA AVENACEA, Linn., var. (?) At San Luis Potosi (1055 Schaffner); 929 Parry & Palmer, and 669 Bourgeau. It was also collected in New Mexico by Wright (1998), and in Arizona by Rothrock (456).

MUHLENBERGIA CALAMAGROSTIDEA, Kunth. At Parras, Coahuila (1348); the same as 218 Bourgeau, so named by Fournier. Also at San Luis Potosi, an undeveloped form (1068 Schaffner).

MUHLENBERGIA CLOMENA, Trin. At San Luis Potosi (1069 Schaffner).

MUHLENBERGIA SCHAFFNERI, Fourn. Same locality (1065 Schaffner).

MUHLENBERGIA BERLANDIERI, Trin. (?) Allied to *M. debilis*, but a stout erect grass, with a long narrow panicle, the glumes about a fourth as long as the flower. At San Luis Potosi (1059 Schaffner); the same as 1992 Wright.

MUHLENBERGIA ——? From Mexico, but the locality uncertain; scanty specimens. The same as 1557 Bourgeau and 679 Botteri, the latter named by Munro *M. capillaris*, from which they differ in the slender decumbent geniculate stems and very short and obtuse glumes.

MUHLENBERGIA SCABRA. Cespitose, erect, a foot high or less, very scabrous throughout and somewhat rigid: leaves mostly basal, erect, flat, ½ to 1½ lines broad, equalling the culm or shorter, the single culm-leaf with a very long sheath; ligule short, fimbriate: panicle contracted, dense, 3 or 4 inches long, the spikelets sessile: lower glumes nearly equal and equalling the flower, thin, scabrous on the keel, the lower acute, the upper obtusish and irregularly toothed, 1½ lines long; flowering glume villous, 2-toothed, bearing a flexuous scabrous rufous awn 6 lines long; palea glabrous. — At San Luis Potosi (1067 Schaffner). A strongly marked species, which appears to be undescribed.

LYCURUS PHALAROIDES, HBK. (*L. phleoides*, HBK.) Same locality (1045 Schaffner); 939 Parry & Palmer. The awns in these specimens vary in length from once to twice that of the glumes.

SPOROBOLUS SABEANUS, Buckl. At Sutherland Springs, Texas. This rather common Texan grass has been referred to *S. Coromandelinus*, Kunth, from which it differs notably in its thin unequal glumes and linear leaves. It is nearer to *S. argutus*, Kunth.

SPOROBOLUS ATROVIRENS, Kunth. At San Luis Potosi (1034 Schaffner).

SPOROBOLUS REPENS, Presl. Same locality (1025 Schaffner); 926 Parry & Palmer. So named at Kew, but differing from 3285 Bourgeau, which was referred by Munro to this species, in the longer and more acuminate lower glumes, which are more than half the length of the flower.

SPOROBOLUS CRYPTANDRUS, Gray. Near Ladrillera, San Luis Potosi (Schaffner, without number).

SPOROBOLUS ——? Near *S. Wrightii*, Munro. At San Luis Potosi (1078 Schaffner).

EPICAMPES ——? Stout, erect (2 to 4 feet high), very pubescent throughout, with a narrow close lead-colored panicle: lower glumes villous, equal, very thin and nerveless, not carinate, usually toothed at the blunt apex; flowering glume similar and equal, a line long, with a slender dorsal awn at the summit; palea villous. — At San Luis Potosi (1023 Schaffner); 933 Parry & Palmer. A very peculiar species. 683 and 1153 Bourgeau ("*E. robusta*, Fourn.") are the same, but glabrous (excepting the flowering glume) or only minutely pubescent.

EPICAMPES ——? A slender stoloniferous perennial, 1 to 1½ feet high, the purplish spikelets approximate upon the short erect branches of the short panicle: lower glumes acuminate, slightly scabrous on the keel; flowering glume shortly villous (1½ lines long), acuminate, with a short awn between the very short terminal teeth. — In the mountains near San Miguelito (1024 Schaffner).

Agrostis verticillata, Vill. At Parras, Coahuila (2019), and at San Luis Potosi (1022 Schaffner).

Agrostis scabra, Willd. At San Luis Potosi (1033 Schaffner).

Microchloa setacea, R. Br. Same locality (1000 Schaffner); 970 Parry & Palmer.

Chloris cucullata, Bisch. At Sutherland Springs, Texas; a single specimen.

Chloris elegans, HBK. (*C. alba*, Presl.) At Parras, and in the Morales Mountains, (1073 Schaffner); 961 Parry & Palmer.

Chloris submutica, HBK. San Luis Potosi (1074 Schaffner).

Chloris ——? Very near *C. verticillata*, Nutt., but the flowers narrower and somewhat longer. Same locality (1072 Schaffner); 445 Bourgeau and 723 Botteri.

Bouteloua tenuis, Griseb. At San Luis Potosi (1011, 1012, 1013 Schaffner). These specimens correspond very closely with the description and figure of *Chondrosium tenue*, HBK. (Nov. Gen. 1. 176, t. 57), and especially in their erect habit and convolute-filiform leaves. The tufts are densely cespitose and the root apparently perennial. The South American specimens referred to this species by Grisebach (Pl. Lorentz. 211, and Symb. Fl. Arg. 303) belong rather to *B. simplex*, Lag.

Bouteloua prostrata, Lag. (*Chondrosium humile*, HBK., l. c., 175, t. 56.) A loosely cespitose slender many-stemmed annual, geniculate and decumbent, or procumbent and rooting at base; leaves ½ to 1 line broad, flat or somewhat convolute. A spike in herb. Gray from Lagasca's original specimens, together with the fuller description given by Roemer & Schultes, leaves little doubt respecting the identification of the species. It differs, however, but little from the South American *B. simplex*, Lag. — At Monclova, Coahuila (1358), and at San Luis Potosi (1016 Schaffner); 751 Bourgeau. Collected also in New Mexico by Fendler (939) and by G. R. Vasey.

Bouteloua scorpioides, Lag. (?) Dwarf, cespitose and stoloniferous, glabrous: leaves mostly flat, ¼ to ½ line wide: culms shorter than the leaves (2 or 3 inches high), bearing a single loose strongly circinate spike about an inch long: spikelets about 15, mostly in pairs: lower glumes very narrow, acuminate, slightly villous, the upper 3 lines, the lower 2 lines long; flowering glume with 3 slender awns (½ inch long) and usually 2 or 3 shorter ones at their base; palea bicuspidate; sterile flower bearded at base, 5–6-awned. — At San Luis Potosi (1010 Schaffner). Lagasca's species is known only from his very short and imperfect description.

Bouteloua hirsuta, Lag. (*Chondrosium hirtum*, HBK., l. c., 176, t. 59. *C. fœneum*, Torr. in Emory's Rep. 153, t. 12.) At San Luis Potosi (1018 Schaffner); 943 Parry & Palmer. The typical form, as shown by spikelets in Herb. Gray from Lagasca's original specimens, differing in the less attenuate or sometimes mucronate teeth of the flowering glume from the more common form northward, which can hardly be considered as distinct. The rhachis of the spike is usually conspicuously produced beyond the spikelets, as often occurs also in the northern variety.

Bouteloua oligostachya, Torr. At San Luis Potosi (1014 Schaffner) and near San Rafael (1015 Schaffner); 448 and 666 Bourgeau; 453 Bilimek; 944 Parry & Palmer, a form with pale slender spikes, the lower glumes nearly naked. This species includes *Chondrosium Aschenbornianum*, Nees, and probably also *C. gracile*, HBK., though the last is figured and described as 1-spicate.

Bouteloua polystachya, Torr. At Guadalupe, Texas (1356), and in the San Rafael Mountains (1020 Schaffner); 946 Parry & Palmer; 667 Bourgeau. 1017 Schaffner, from San Luis Potosi, is a dwarf prostrate form, with very short awns. — Var. vestita, with the lower glumes very villous. In the Sierra Madre, south of Saltillo (1357), and near Morales, San Luis Potosi (1019 Schaffner); 943½ Parry & Palmer.

Bouteloua (Chondrosium) trifida, Thurber, Gram. Mex. Bound. ined. A densely cespitose perennial, glaucous, sparingly villous on the margins of the flat or subrevolute rather short leaves: culms slender, erect, a foot high or less: spikes 3 to 5, slender, nearly straight, glabrous, 6 to 9 lines long: lower glumes scarious, narrowly lanceolate, nearly equal; flowers glabrous, the flowering glume cleft into 3 long nearly equal awns; sterile glume also 3-awned. — Somewhat resembling *B. eriopoda*, Torr., in habit. At Monclova, Coahuila (1355); 945 Parry & Palmer. It is also 749, 2020 and 2022 Wright.

Bouteloua racemosa, Lag. At San Luis Potosi (1061 Schaffner); 2755 and 451 Bourgeau. Spikes of 2 to 8 purplish spikelets, the sterile flower reduced to a minute awn, or rarely more developed in the uppermost spikelet, and with the awn exserted. Its farther development into a triple awn, which frequently occurs in the common form of the Northern States (*B. curtipendula*, Torr.), is evidently insufficient for a separation of the species.

Bouteloua bromoides, Lag. (*Heterostegia juncifolia*, HBK., Nov. Gen. 1. 173, t. 54. *Dinebra repens*, HBK., l. c., 172, t. 52. *Bouteloua Humboldtiana*, Griseb. Probably also *Dinebra bromoides*, HBK., l. c., t. 51.) In the Caracol Mountains, Coahuila (1354), and at San Luis Potosi (1001 to 1003 Schaffner). Somewhat variable in size, habit, and number of spikelets, but the floral characters uniform within narrow limits in all the specimens examined from the United States, Mexico, Panama and the West Indies. The second floret is usually staminiferous, and the third reduced to a rudimentary awn, often very short. It was found in no case 3-awned, as shown in the figure of *Heterostegia juncifolia.* Dr. Palmer's specimens represent a large form with large spikes (the same as 2024 Wright and 450 Bourgeau), corresponding to *Dinebra bromoides*, HBK., though that seems to have been based upon specimens with the second flower less developed than usual. Schaffner's specimens are smaller and decumbent, according in every respect with *Dinebra repens*, HBK.; 534 Bourgeau is the same. There can be little hesitation in referring all to Lagasca's species.

BOUTELOUA ARISTIDOIDES, Thurb. At Soledad, Coahuila (1353), and at San Luis Potosi (1062 Schaffner); 941 Parry & Palmer.*

BUCHLOE DACTYLOIDES, Engelm. At San Luis Potosi (1004 and 1021 Schaffner, the staminate and pistillate forms); 922 and 953 Parry & Palmer.

PAPPOPHORUM WRIGHTII. Flowering glume 9-nerved and 9-

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* A study of the material in the Gray Herbarium has led to the following arrangement and identification of the species of *Bouteloua*. The sections are as proposed by Mr. Bentham. The synonymy is complicated, and some of Lagasca's species yet remain uncertain, owing to his very brief and imperfect descriptions. His *B. barbata* appears to belong to the section *Chondrosium*, and *B. juncifolia* and *B. ovata* to *Atheropogon*.

§ 1. *Chondrosium*, Gray. Spikes one to several, linear or oblong, more or less falcate, the usually very numerous spikelets pectinately crowded on one side of the rhachis: terminal empty glume usually 3-awned.

* Spike always solitary.

+ Lower glumes glabrous.

1. B. TENUIS, Griseb. (in part). Mexico. See page 176.
2. B. PROSTRATA, Lag. Western Texas and New Mexico to Mexico. See page 176.
3. B. SIMPLEX, Lag. Andes of South America.

+ + Lower glumes villous.

4. B. SCORPIOIDES, Lag. Mexico. See page 176.

* * Spikes usually 2 or more.

+ Spikes oblong-linear, very dense: lower glumes villous.

5. B. HIRSUTA, Lag. Pedicel of sterile glume glabrous. — Illinois to Texas, Arizona, and Mexico; Florida. See page 177.

awned; sterile glume 9-awned. — Our only species of the section *Enneapogon*. At Parras (1361); 947 Parry & Palmer; 751 and 2029 Wright, referred to *P. boreale*, Griseb., by Torrey (Pacif. Railroad Rep. 4. 155). Differing from that Siberian species in its more pilose nodes and ligules, longer and narrower panicles, glumes rather more strongly nerved, flowers smaller and more villous, and the seed broader and more ovate. Its resemblance to *P. nigricans*, Br. (*P. pallidum*

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6. B. OLIGOSTACHYA, Torr. Pedicel of sterile glume bearded. — From the Saskatchewan to Texas, Arizona, Southeastern California, and Mexico. See page 177.

+ + Spikes narrowly linear, dense: glumes usually glabrous.

7. B. POLYSTACHYA, Torr. Flowering and sterile glumes 3-awned, with usually broad lobes between the awns. — From Southern Utah to Texas, Southern California, and Mexico. See page 177.

+ + + Spikes more loose and slender: lower glumes glabrous.

++ Flowering and sterile glumes bearded at base, 1-awned: peduncle villous.

8. B. ERIOPODA, Torr. Western Texas and New Mexico.

++ ++ Flowering and sterile glumes naked, 3-awned: peduncle smooth.

9. B. TRIFIDA, Thurber. Western Texas, New Mexico, and Mexico. See page 177.

10. B. BURKEI, Scribner, *ined.* Smaller, the spikes shorter, the flowering glume short-villous, and the awns shorter. Western Texas and New Mexico. (167 and 1427 Berlandier, 3440* Curtiss).

§ 2. *Atheropogon*, Gray. Spikes several or numerous, usually short, straight, not pectinate, the few (3 to 12) spikelets often fascicled: the terminal empty glume 3-awned, or more or less reduced and rudimentary.

11. B. RACEMOSA, Lag. (*B. curtipendula*, Torr.) From New York and Pennsylvania to Wisconsin, and south to Texas, Arizona and Mexico; South America. See page 177.

12. B. BROMOIDES, Lag. From Western Texas to Arizona and Mexico; Central America. See page 177.

13. B. HAVARDI, Vasey, *ined.* Perennial, villous, erect: spikes (4 or 5) half an inch long or less, very silky-villous: lower glume acuminate; flowering glume 3-cleft to the middle, the teeth stout, acuminate, villous; palet as long, acuminate, villous on the back: sterile glume naked, reduced to 3 awns twice longer than the fertile flower, the middle one subulate below, the lateral sometimes villous. — Limpio Mountains, Western Texas; 753 Wright, 1849; Dr. V. Havard, 1881.

14. B. CHONDROSIOIDES, Benth. (*Dinebra chondrosioides*, HBK., Nov. Gen. 1. 173, t. 53.) Mexico. (Not seen.)

15. B. LITIGIOSA, Lag. (*B. porphyrantha*, Wright); and 16. B. ELATIOR, Griseb. West Indies. (The last not seen.)

17. B. CILIATA, Griseb., 18. B. LOPHOSTACHYA, Griseb., and 19. B. NANA, Griseb. South America. (Not seen.)

20. B. PILOSA, Benth. (*Eutriana pilosa*, Hook. f.) Galapagos Islands.

Br.), has been noted, which Australian species has blunter and much more strongly nerved glumes; it is also smoother, and the awns of the still more villous flowering glume are plumose nearly to the summit.

Pappophorum apertum, Munro in herb.; Scribner, Bull. Torr. Club, 9. 148. Glabrous or nearly so, except the villous throat of the sheath, erect or geniculate at base, 2 or 3 feet high: panicle close and spike-like or at length somewhat open, 4 to 9 inches long; spikelets 4–5-flowered, the uppermost flowers abortive: lower glumes very thin and scarious, 1-nerved, acutish, irregularly 2–3-toothed at the apex; flowering glume with 5 green nerves above, irregularly cleft into about 15 naked awns, which are scarcely twice longer than the undivided base (a line long). — At Parras (1360) and Monclova, Coahuila (1362). Near *P. alopecuroides*, Vahl, which has naked sheaths, still longer panicles, longer acuminate glumes, and smaller flowers, the slender awns several times longer than the short base.

Triodia pulchella, HBK. (*Tricuspis pulchella*, Torr.) At Parras, Coahuila (1359), and at San Luis Potosi (1007 Schaffner); 951 Parry & Palmer.

Triodia avenacea, HBK. Running freely. At San Luis Potosi (1008 Schaffner); 950 Parry & Palmer. Also a taller erect form, described as not stoloniferous; same locality (1009 Schaffner).

Triodia mutica, Benth. (*Tricuspis mutica*, Torr. *Uralepis pilosa* and *U. elongata*, Buckl.) Mountains west of Saltillo (2020). What has been named "*Tricuspis trinerviglumis*, Munro," appears to be in every respect the same.

Triodia Texana. (*Tricuspis Texana*, Thurb. in herb.) A slender erect cespitose perennial, 2 feet high, more or less pubescent throughout with short spreading hairs, the nodes glabrous: leaves very narrow (a line broad or less), the sheaths villous at the throat:

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§ 3. *Triathera*, Benth. Spikes several, short and narrow, the 1 to 3 slender spikelets closely appressed to the rhachis: terminal glume reduced to a triple awn.

21. B. aristidoides, Thurb. From New Mexico to Southern California and Mexico.

22. B. triathera, Benth. (*Triœna racemosa*, HBK., l. c., t. 61.) Mexico. (Not seen.)

§ 4. *Polyodon*, Benth. Spikes few, short, of few spikelets: flowering glume 3-awned, the 2 or 3 terminal empty ones crowded together and each 3–5-awned.

23. B. Texana, Watson. Texas. See page 196.
24. B. disticha, Benth. (*Polyodon distichum*, HBK., l. c., t. 55.) Peru.
25. B. multiseta, Benth. Brazil. (These not seen.)

panicle very diffuse, the branchlets pubescent; spikelets ovate-oblong, 6–10-flowered; glumes thin, 1-nerved, blunt or shortly mucronate, glabrous; flowering glume villous toward the base upon the 3 green nerves, the middle nerve shortly excurrent between the short teeth; palea glabrous. — At Monclova, Coahuila (1371); also in Western Texas and New Mexico (776, 777 and 2045 Wright).

Triodia Schaffneri. A dwarf cespitose slender annual (?), with fibrous roots, very sparingly villous, the culms 2 or 3 inches high, exceeding the very narrow leaves and bearing a single somewhat 1-sided spike (1 to 1½ inches long) of rather scattered greenish spikelets (8 to 15), which are linear-lanceolate, 6–10-flowered, 2 lines long; rhachis of the spikelets villous-pubescent: lower glumes glabrous, carinate, 1-nerved, obtusish, finely toothed at the apex; flowering glume glabrous, 3-nerved, the lateral nerves ceasing below the margin, the middle produced into a short awn between the broad obtuse teeth. — In the Escabrillos Mountains, San Luis Potosi (1077 Schaffner). Closely resembling in habit the Cuban *Tricuspis simplex* of Grisebach, and *Diplachne spicata*, Doell, of Brazil. It is clearly a *Triodia*, as the genus is defined by Mr. Bentham.

Leptochloa mucronata, Kunth. At Monclova (1364).

Diplachne fascicularis, Beauv. At San Luis Potosi (1048 Schaffner).

Diplachne dubia, Benth. At the same locality (1079 Schaffner).

Scleropogon Karwinskyanus, Benth. (*Lesourdia Karwinskyana*, Fourn. in Bull. Soc. Bot. France, 27. 102, t. 4, fig. 12.) At San Luis Potosi (1005 Schaffner) and near Morales (1006 Schaffner); 925 and 949 Parry & Palmer. Perennial; very variable in length of awns (1 to 5 inches), their number, etc. Fournier's *Lesourdia multiflora* (l. c., t. 3, 4) appears to be only a short-awned form. As stated by Bentham, both staminate and pistillate spikes occur on the same plant. They are not rarely on the same culm. The plant is common in New Mexico, and was referred by Munro to *Tricuspis*, — by Torrey to *Aristida*.

Arundo Donax, Linn. At Monclova, Coahuila (1345).

Eragrostis reptans, Nees. At Sutherland Springs, Texas (1369); 1154 Parry & Palmer.

Eragrostis oxylepis, Torr. At the same locality (1370).

Eragrostis minor, Host. (*E. poœoides*, Beauv.) At San Luis Potosi (1027 Schaffner).

Eragrostis major, Host. (*E. megastachya*, Link.) At the same locality (1031 Schaffner); 934 Parry & Palmer. Also a form with few-flowered spikelets (1030 Schaffner); 934½ Parry & Palmer. The genus *Eragrostis* is usually credited to Beauvois (1812), but was first proposed (though without a character) by Host (1809), who referred to it these two species, which represent Beauvois' two genera *Eragrostis* and *Megastachya*.

Eragrostis pilosa, Roem. & Schult. At San Luis Potosi (1028 Schaffner). Identical with 662 Botteri (in Herb. Gray), so named by Munro, and the same as 937 Fendler, and 437, 445, 2594, and 2637 Bourgeau.

Eragrostis lugens, Nees. At San Luis Potosi (1026 Schaffner); 938 Parry & Palmer. A common grass from Texas (and eastward) to Arizona and Mexico, allied to *E. capillaris*, Nees. It is more or less villous on the sheaths and at the nodes of the panicle, or often nearly glabrous, the narrow spikelets of 3 to 5 (rarely 6) flowers, the strongly concave bluntish flowering glumes nearly nerveless. It is 329 Drummond, 936 Fendler, 2050 Wright, 788 Hall ("*E. capillaris*"), Pringle's "*E. pilifera*," 228, 673 and 2643 Bourgeau, and 681 and 682 Botteri (so named by Munro).

Eragrostis Mexicana, Link. At Parras, Coahuila (1367), and at San Luis Potosi (1029 Schaffner); 936 Parry & Palmer. Another common species of Mexico and the region adjacent on the north, allied to *E. tenuis*, Gray, but with blunter and closer glumes. *E. pilifera*, Scheele, is probably the same. It includes 2046, 2047 and 2052 Wright, 604 Rothrock, and 1031, 1305 and 2625 Bourgeau.

Eragrostis Palmeri. Culms numerous, slender, erect from a creeping rootstock, 2 or 3 feet high: leaves narrow (1 or 2 lines wide), becoming revolute: panicle open, glabrous; spikelets sessile or shortly pedicellate upon the slender branches, narrowly lanceolate, acute, 3–8-flowered, 1½ to 2½ lines long: lower glumes acuminate, scabrous on the keel; flowering glume concave, rather faintly 3-nerved, acute, slightly scabrous on the keel toward the top. — At Juraz, on the Sabinas River, Coahuila (1368). Allied to *E. lugens*, but the spikelets mostly nearly sessile and the flowering glumes more strongly nerved.

Briza rotundata, Steud. At San Luis Potosi (1035 Schaffner); 935 Parry & Palmer.

Poa annua, Linn. At Monterey (1365), and San Luis Potosi (1032 Schaffner).

Poa Ruprechtii, Peyr. in Linnæa, 30. 6. In the mountains east of Saltillo (1366). So named at Kew; scarcely, if at all, distinct from *P. flexuosa*, Muhl.

Bromus ciliatus, Linn. At San Luis Potosi (1075 Schaffner). Also a variety, with the panicle sparingly puberulent or glabrate; in the Sierra Madre, south of Saltillo (1372).

Brachypodium cæspitosum, Roem. & Schult. At San Luis Potosi (1076 Schaffner).

The following list of the Ferns and other vascular Acrogens, including all those of the Parry & Palmer collection, has been furnished by Prof. Daniel C. Eaton. The Mosses were determined by the late Thomas P. James, Esq., and the remaining lower cryptogams by Prof. W. G. Farlow.

Acrostichum venustum, Fée. In the San Rafael Mountains (954 Schaffner). Sent under this name from Kew, but not agreeing well with the character of the species as described by Fée.

Acrostichum gratum, Fée. In the San Miguelito Mountains (953 Schaffner); 1007 Parry & Palmer (1009 in some sets).

Polypodium ellipsoideum, Fée. In the San Miguelito Mountains (941 Schaffner).

Polypodium Martensii, Mett. At San Luis Potosi; 973½, in part, and 974½ Parry & Palmer. The bright scales of the rootstock are very showy.

Polypodium plebeium, Schlecht. The dried fronds have a yellowish-green color, and the specimens are of the form called *P. oulolepis* by Fée. In the Sierra Madre, southeast of Saltillo (1373), and in the San Miguelito Mountains (940 Schaffner); 973 and 974 Parry & Palmer. Popularly known as "Calaguala" (as are several other species), and used as an expectorant.

Polypodium cheilosticton, Fée. 973½ Parry & Palmer, in part. This seems to be a good species; it is also 206 and 400 Ghiesbreght, and 18 Mohr, from Orizaba.

Polypodium subpetiolatum, Hook. In the Lerios Mountains, near Saltillo (Palmer, not numbered). Small specimens, which agree best with this species.

Polypodium furfuraceum, Schlecht. In the route from San Luis Potosi to Tampico (1155 Palmer, coll. of 1878–79); Orizaba (31 Mohr).

Polypodium incanum, Swartz. On the Caracol Mountains, Coahuila (1376), and at Guajuco (no number). Also on the route from San Luis Potosi to Tampico (1155½, coll. of 1878–79).

Polypodium aureum, Linn., var. **areolatum**. In the mountains of San Rafael (942 Schaffner); 972 Parry & Palmer.

POLYPODIUM THYSSANOLEPIS, Al. Br. In the mountains near San Luis Potosi (939 Schaffner); 971 Parry & Palmer. Also at Orizaba (36 Mohr), and in the Huachuca Mountains, Arizona (Lemmon).

POLYPODIUM PLESIOSORUM, Kunze. Guajuco, Nuevo Leon (1374).

POLYPODIUM LANCEOLATUM, Linn. In the mountains of San Miguelito (938 Schaffner); 975, 975½ Parry & Palmer.

GYMNOGRAMME PEDATA, Kaulf. In the mountains of San Rafael (960 Schaffner); collected also by Bourgeau (758), and in Chiapas (315 Ghiesbreght).

GYMNOGRAMME EHRENBERGIANA, Klotzsch. In the Escobrillos Mountains (928 Schaffner); 1006 Parry & Palmer. Western Texas to Arizona (Wright, King, Rothrock, Rusby, etc.). This is the *G. hispida* of Mettenius, and *G. podophylla*, Hooker, at least as to the New Mexican specimens. The veins are free in some fronds, and netted in others, from the same lot of specimens. Klotzsch's name has priority over the others.

GYMNOGRAMME TARTAREA, Desv. In the San Miguelito Mountains (929 Schaffner).

GYMNOGRAMME CALOMELANOS, Desv. At San Luis Potosi; 985 Parry & Palmer.

NOTHOLÆNA SINUATA, Kaulf. At many stations in Coahuila and Nuevo Leon, in a great variety of forms, from the fully developed type down to the smallest with minute entire pinnæ (1400 to 1410); in the Escobrillos Mountains (947 Schaffner); 995, 995½, 996 and 997 Parry & Palmer.

NOTHOLÆNA BRACHYPUS, J. Smith. In the region of San Luis Potosi (998 Parry & Palmer). The hairs of the lower surface are very evident when the scales are removed, and it is perhaps safest to follow Kuhn (Beitr. p. 4) in keeping this separate from *N. squamosa.*

NOTHOLÆNA FERRUGINEA, Hooker. At Soledad (1399); San Miguelito Mountains (946 Schaffner); 993 and 994 Parry & Palmer.

NOTHOLÆNA ASCHENBORNIANA, Klotzsch. At Lerios in the high mountains east of Saltillo, and near Monterey (without number). This has been attributed to Texas, and was found in 1882 on the Huachuca Mountains of Arizona by J. G. Lemmon.

NOTHOLÆNA GRAYI, Davenport. At Soledad, Coahuila (1388, with white powder, and 1389, with yellowish powder). In the San Rafael Mountains, with fronds ten inches high, the powder white (962 Schaffner).

NOTHOLÆNA HOOKERI, Eaton. At Saltillo, and San Lorenzo de Laguna, Coahuila (1379); 992 Parry & Palmer.

NOTHOLÆNA CANDIDA, Hooker. At Guajuco in Nuevo Leon, and in mountains northeast of Monclova, Coahuila (1380); near Monterey (1381).

NOTHOLÆNA NIVEA, Desv. At Monterey, Nuevo Leon (1386), and in the San Rafael Mountains (961 Schaffner). — Var. FLAVA, Hooker, was collected at Lerios (1387), and a form with smaller and more distant pinnules, the powder white, in the Sierra Madre, south of Saltillo (1385). A *Notholæna* with fronds 3 to 4 inches long, narrower in outline, and with closely placed subcoriaceous pinnules, which may be a form of this species, was found at several places in Coahuila and Nuevo Leon (1382, 1383, 1384). 991 Parry & Palmer is closely allied to these last, but has the short-stalked frond slightly narrowed at the base, and may prove a distinct species. Mr. Davenport pronounces *N. dealbàta* only a slender form of *N. nivea*, and the various intermediate forms, now common in herbaria, justify his view.

CHEILANTHES MEIFOLIA. Rootstock short, creeping, chaffy with very narrow acuminate rigid blackish scales: stalks tufted, dark-stramineous, smooth and shining, slender, 6 to 9 inches long; frond 2 or 3 inches long and nearly as broad, deltoid, smooth, 4 or 5 times pinnate and cut into innumerable very narrow linear-acuminate segments: involucres terminal on the segments, orbicular, delicately membranaceous. — At Guajuco, Nuevo Leon (1377). Closely allied to *C. Californica*, but with the involucres terminal and rounded, instead of lateral and crescent-shaped.

CHEILANTHES WRIGHTII, Hooker, var. (?) At Soledad, Coahuila (1378). More finely divided than *C. Wrightii*, and sparingly chaffy along the rhachis, but with the same herbaceous texture and similar involucres.

CHEILANTHES ALABAMENSIS, Hooker. At Georgetown, Williamson Co., Texas (1415); a few specimens were also collected at Guajuco, Nuevo Leon, and in the mountains east of Saltillo.

CHEILANTHES MICROPHYLLA, Swartz. At many stations in Texas, Coahuila and Nuevo Leon, and showing a great variety of forms, some of very large size (1411 to 1414, 1416, 1418 to 1421); 981 and 986 Parry & Palmer. — Var. ASPIDIOIDES, Fée. At Soledad, Coahuila (1417), and in the San Miguelito Mountains (920 Schaffner); 984½ Parry & Palmer.

CHEILANTHES COOPERÆ, Eaton. A few specimens not safely separable from this species were collected by Parry & Palmer (989) in the region about San Luis Potosi.

CHEILANTHES VISCOSA, Link. In the San Miguelito Mountains (926 Schaffner); 990 Parry & Palmer. *Pellæa glauca*, J. Smith, seems in no way different from this.

CHEILANTHES TOMENTOSA, Link. At Soledad, Coahuila (1395, 1396). Also a form with very large pinnules from the Caracol Mountains (1391). — Var. EATONI, Davenport. (*C. Eatoni*, Baker.) At Soledad, Coahuila (1394), at Guajuco, Nuevo Leon (1393), in the mountains east and south of Saltillo (1397, 1398), and in the San Miguelito Mountains (910 Schaffner); 999½ Parry & Palmer.

CHEILANTHES GRACILLIMA, Eaton. A form much larger than the usual Californian specimens. In the Sierra Madre, south of Saltillo (1390).

CHEILANTHES CINNAMOMEA. (*Myriopteris rufa*, Fée.) In the San Miguelito Mountains, San Luis Potosi (911 Schaffner), and in the San Rafael Mountains (914 Schaffner). The species of the *Myriopteris* group of this genus are very perplexing, and in the absence of authentic specimens often very difficult to identify. The plant here referred, not without hesitation, to one of Fée's species, has an elongated cord-like rhizoma, fronds 3 to 8 inches long, 3–4-pinnate with closely set minute bead-like pinnules, smooth and green above, but beneath heavily covered like the rhachis with a coarse entangled tomentum of a bright-ferruginous color. Some of the smallest fronds have the lower pinnules "*écartées*" as Fée describes them. *C. cinnamomea*, as understood, differs from the large form of *C. gracillima* in the elongated rootstock and in the much coarser woolly covering of the pinnules beneath. The name *rufa* is preoccupied in this genus.

CHEILANTHES LINDHEIMERI, Hooker. In Uvalde Cañon, 90 miles northwest of San Antonio, Texas (1392), and in the Escobrillos Mountains (937 Schaffner); 999 and 999½ Parry & Palmer. Schaffner's specimens were marked "*Myriopteris cheiloglyphis*, Fée," a plant unknown in American herbaria; but they do not at all agree with Fée's description.

CHEILANTHES MYRIOPHYLLA, Desv. In the Escobrillos Mountains (912 Schaffner), and in the mountains about Morales (915 Schaffner) and San Miguelito (916 Schaffner); 987 and 988 Parry & Palmer.

CHEILANTHES CLEVELANDII, Eaton. In the Escobrillos Mountains (913 Schaffner). The cord-like rhizoma is wanting, but the fronds are evidently like those of the San Diego specimens.

CHEILANTHES FARINOSA, Kaulf. In the San Rafael Mountains (963 Schaffner).

PELLÆA RIGIDA, Hooker. On the route from San Luis Potosi to Tampico (1156 Parry & Palmer), and at Orizaba (40 Mohr).

PELLÆA SEEMANNI, Hooker. Fronds larger and more compound than shown in Hooker's figure, but otherwise well agreeing with the character of the species. In the Morales Mountains (923 Schaffner); 979 Parry & Palmer.

PELLÆA ATROPURPUREA, Link. At Georgetown, Texas (1425), and (without number) in the Caracol Mountains, and near Saltillo, Coahuila.

PELLÆA ASPERA, Baker. In the mountains northeast of Monclova, Coahuila (1422); also collected sparingly in Southwestern Texas.

PELLÆA PULCHELLA, Fée. At Soledad (1423), and at Lerios (1424).

PELLÆA MARGINATA, Baker. In the San Miguelito Mountains (921 Schaffner), and San Rafael Mountains (922 Schaffner, a smaller form); 983 Parry & Palmer.

PELLÆA TERNIFOLIA, Link. In the Escobrillos Mountains (924 Schaffner); 982 Parry & Palmer.

PELLÆA CORDATA, J. Smith. Fine typical specimens, with broad orbicular-cordate pinnules, were gathered in the region of San Luis Potosi by Parry & Palmer (980); in the mountains of San Rafael (959 Schaffner), a form with narrower pinnules; near Saltillo, Coahuila (1426, 1427), a form with still smaller pinnules, evidently passing into the New Mexican and Arizona plant formerly referred to *P. andromedæfolia*, var. *pubescens*, but which Mr. Davenport thinks should rather be joined with this species.

PELLÆA FLEXUOSA, Link. In Uvalde Cañon, Texas (1428), also without number from Soledad and Monterey, and in the San Miguelito Mountains (958 Schaffner). This is made a variety of the last species by Mr. Baker, but in well-developed fronds the zigzag habit is very conspicuous, and it is perhaps as well to keep the two apart.

LLAVEA CORDIFOLIA, Lagasca. At Guajuco, Nuevo Leon (1375).

PTERIS AQUILINA, Linn. In Wilson Co., Texas (1429). — Var. LANUGINOSA, Bongard. In the San Miguelito Mountains (925 Schaffner).

ADIANTUM CAPILLUS-VENERIS, Linn. At Saltillo, and San Lorenzo de Laguna, Coahuila (1430, 1431), and in the mountains of Morales and San Rafael (930, 932 Schaffner); 977 Parry & Palmer, in part.

ADIANTUM THALICTROIDES, Willd. In the San Miguelito Mountains (931 Schaffner); 977 Parry & Palmer, in part. This is a very distinct species, as is well shown by Keyserling. Fendler's Venezuelan 71 is also an example of it, as pointed out by Fournier.

ADIANTUM TENERUM, Swartz. At Guajuco, Nuevo Leon (Palmer, without number, a single frond).

BLECHNUM OCCIDENTALE, Linn. In the mountains around the city of San Luis Potosi (952 Schaffner).

ASPLENIUM TRICHOMANES, Linn. At Soledad, Coahuila (1435), and in the San Miguelito Mountains (917 Schaffner).

ASPLENIUM PARVULUM, Mart. & Gal. At Georgetown, Texas (1436).

ASPLENIUM MONANTHEMUM, Linn. In the San Miguelito Mountains (918 Schaffner); 978, 978½ Parry & Palmer. The pinnæ are very often plurisorous, and when this character is seen in fronds of small size, the specimens are not easily distinguished from large forms of *A. Trichomanes*.

ASPLENIUM FURCATUM, Thunb. In the San Miguelito Mountains (956 Schaffner).

ASPLENIUM PUMILUM, Swartz. On the route from San Luis Potosi to Tampico (1157 Palmer, coll. of 1878).

ASPIDIUM ACULEATUM, Swartz. In the Escobrillos Mountains, small but characteristic specimens (950 Schaffner). — Var. MORITZIANUM. (*A. Moritzianum*, Kunze.) In the San Rafael Mountains (948 Schaffner).

ASPIDIUM PATENS, Swartz. At Sutherland Springs and Uvalde Cañon, Western Texas (1432, 1433), and in the San Miguelito Mountains (965 Schaffner).

ASPIDIUM ATHYRIOIDES, Mart. & Gal. (*Nephrodium sphærocarpum*, Hooker.) In the Morales Mountains (951 Schaffner), and in the San Miguelito Mountains, young plants, not yet producing large fronds, but still fruiting (949 Schaffner).

ASPIDIUM TRIFOLIATUM, Swartz. At Guajuco (1437).

CYSTOPTERIS FRAGILIS, Bernh. In the region of San Luis Potosi (1001, 1002 Parry & Palmer); on the route to Tampico (1158 Palmer, in 1878).

WOODSIA MOLLIS, J. Smith. In the San Rafael Mountains (957 Schaffner); also collected by Bourgeau (459).

WOODSIA OBTUSA, R. Br. (?) Sterile fronds only, collected at Bluffton, Burnet Co., Texas (1434).

WOODSIA MEXICANA, Fée. At Soledad, Coahuila (Palmer, not numbered), and in the San Miguelito Mountains (927 Schaffner); 1000 Parry & Palmer, in some sets having *W. mollis* intermixed.

LYGODIUM MEXICANUM, Presl. On the route from San Luis Potosi to Tampico (1159 Palmer, in 1878).

ANEIMIA MEXICANA, Klotzsch. In the Caracol Mountains, Coahuila (1438); also a few specimens at Guajuco, Nuevo Leon.

ANEIMIA TOMENTOSA, Swartz, var. FULVA, Hooker & Baker. In the Escobrillos Mountains (945 Schaffner).

ANEIMIA ADIANTIFOLIA, Swartz. On the route from San Luis Potosi to Tampico (1160 Palmer, in 1878).

BOTRYCHIUM TERNATUM, Swartz. Well-developed, nearly typical specimens, in the mountains of San Miguelito (944 Schaffner).

BOTRYCHIUM VIRGINIANUM, Swartz. With the last (943 Schaffner).

EQUISETUM ROBUSTUM, Al. Braun. In swamps near Morales (964 Schaffner).

SELAGINELLA RUPESTRIS, Spring. In the mountains near San Luis Potosi (933 Schaffner).

SELAGINELLA LEPIDOPHYLLA, Spring. At Monterey (1439), Soledad (1440), and in the Escobrillos Mountains (935 Schaffner).

SELAGINELLA CUSPIDATA, Spring. At Soledad, Coahuila (1441), and in the San Miguelito Mountains (934 Schaffner).

SELAGINELLA PILIFERA, A. Braun. In the region of San Luis Potosi (1008 Parry & Palmer). This is given on the authority of Mr. Baker in a letter to Dr. Parry. The same letter gives n. 1009 as *S. cuspidata;* but in the set of specimens at New Haven, n. 1009 is an *Acrostichum.*

SELAGINELLA SACCHARATA, A. Braun. From the San Rafael Mountains (936 Schaffner); so named at Kew.

MARSILIA MEXICANA, A. Braun. In the region of San Luis Potosi (1010 Parry & Palmer). So named by Mr. Baker.

WEISSIA LONGIROSTRIS, Schwægr. (?) At Guajuco, Nuevo Leon (Palmer).

CERATODON PURPUREUS, Brid. Mexico (Palmer). Not purple.

TRICHOSTOMUM STRICTUM, Bruch. (?) At Guajuco (Palmer). Differing in its perichætial leaves and longer operculum.

TRICHOSTOMUM SCHLIMII, Muell. (?) Mexico (Palmer).

BARBULA CIRRHATA, Muell. In the Sierra Madre, south of Saltillo (Palmer).

BARBULA OBTUSISSIMA, Muell. Mexico (Palmer).

PTYCHOMITRIUM SERRATUM, Schimp. Mexico (Palmer).

BRYUM ARGENTEUM, Linn. In the Caracol Mountains, Coahuila (Palmer).

SYMBLEPHARIS HELICOPHYLLA, Montg. (?) At Guajuco (Palmer). Sterile specimens. The vaginate portion of the leaf has a delicate margin of slender cells, which increase gradually in number toward the middle, from two to five.

BARTRAMIA GARDNERI, Muell. (?) At Morales, San Luis Potosi (Schaffner).

POGONATUM CUCULLATUM, Hampe. At San Miguelito (Schaffner).

NECKERA EHRENBERGII, Muell. Same locality (Schaffner).

CYLINDROTHECIUM COMPRESSUM, Bruch. & Schimp. (?) Mexico (Palmer).

PYLAISÆA INTRICATA, Bruch. & Schimp. In the Sierra Madre, south of Saltillo (Palmer).

HYPNUM ADNATUM, Hedw. (?) Same locality (Palmer).

HYPNUM HUEFLERI, Juratz. Mexico (Palmer).

METZGERIA PUBESCENS, Raddi. In the San Miguelito Mountains (Schaffner).

MADOTHECA MEXICANA, Hampe. On trees near Morales (Schaffner).

NITELLA CLAVATA, A. Braun. At San Luis Potosi (Schaffner).

NITELLA ASAGRÆANA, Schaffner. Same locality (Schaffner).

DOTHIDEA PERISPORIOIDES, B. & C. Same locality (Schaffner).

USTILAGO MAYDIS, Corda. Same locality (Schaffner).

The following additions and corrections are to be made in the previous list of the *Polypetalæ* of these collections.

CEDRELA DUGESII. The fruit of the uncertain species mentioned on page 335, since received from Prof. Dugès, permits a fuller description of this as an apparently very distinct species. Leaflets 3 pairs or more, lanceolate with a long slender acumination, 4 to 6 inches long, rather thin, entire, the veins rusty and slightly pubescent beneath: panicle rather dense and contracted, the pedicels shorter than the calyx; corolla 2½ lines long, pubescent: fruit oblong, about an inch long: seeds with the wing scarcely as long as the body, 3 lines broad or less.

COLUBRINA TEXANA, Gray. At Uvalde, Texas (170), and San Lorenzo de Laguna, Coahuila (169).

INDIGOFERA LEPTOSEPALA, Nutt., var. BREVIPES. At Monterey (236). In some of the sets this will be found to be *Astragalus Nuttallianus*. — Var. (?) ANGUSTATA. In the Sierra Madre, south of Saltillo (255).

Hoffmanseggia Jamesii, Torr. & Gray. At Saltillo (269).

Calliandra eriophylla, Benth. In the mountains north of Monclova (319).

Cotoneaster denticulata, HBK. In the Sierra Madre (785).

Cuphæa cyanea, DC. In the mountains east of Saltillo (775).

Turnera diffusa, Willd., var. aphrodisiaca, Urban, Jahrb. Bot. Gard. Berl. 2. 127. *T. aphrodisiaca*, Ward, is thus referred by Urban, with very good reason.

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2. *Descriptions of some New Western Species.*

Greggia linearifolia. With the habit of *G. camporum*, but the leaves linear, attenuate to the base, entire, 1 or 2 inches long; pod narrower, 6 lines long or less, and less than a line broad; style shorter (not a line long), and stigmas smaller. — At Presidio on the Rio Grande (Wright, in 1848); bluffs of Delaware Creek, Western Texas (Dr. V. Havard, 1882); and at Parras, Coahuila (46 Palmer, 1880), referred to *G. camporum* as a variety.

Sagina crassicaulis. Stout, much branched, glabrous, apparently perennial with slender rootstocks, decumbent: leaves broadly linear, pungent, fleshy, 2 to 6 lines long, united at base into a broad scarious sheath: pedicels often 4 to 8 lines long: flowers mostly erect, large, the sepals exceeding the petals, over a line long: styles very short: capsule ovate, scarcely exserted. — On Dillon's Beach, Marin County, California (J. W. Congdon, June, 1880). Resembling *S. maxima*, Gray, of Japan.

Montia Howellii. A very slender diffuse annual, the stems ½ to 3 inches long, procumbent and rooting: leaves very narrowly linear-spatulate, 2 to 4 lines long, with a dilated scarious clasping base, very rarely opposite, usually opposite to a triangular scarious clasping bract which subtends a few- (usually 3-) flowered cluster; pedicels shorter than the leaves, reflexed in fruit: flowers very small; petals 3 or 4, unequal, slightly united at base, the longer ones slightly exserted: stamens 3, hypogynous: stigmas 3, short: capsule ovate, about equalling the calyx, 3-valved, 3-seeded: seeds black, smooth and shining. — Collected on Sauvies Island, in the Willamette River, Oregon, by Joseph and Thomas Howell, who recognized most of its peculiarities. It agrees in most of its characters with *Montia* as distinguished from *Claytonia*, though some species of the latter genus (as *C. dichotoma* and *C. linearis*) have often but 3 stamens and the petals unequal.

The leaves are occasionally opposite, as in *M. fontana*, which in turn sometimes has one of a pair reduced to a scarious bract. The valves of the capsule in this species are shown by the microscope to be beautifully cancellated.

ASTRAGALUS MATTHEWSII. Very shortly caulescent and cespitose, villous-pubescent with rather short subappressed hairs: leaflets about 12 pairs, obovate to oblong-obovate, 2 to 5 lines long: peduncles equalling the leaves, bearing loose racemes with green lanceolate bracts: calyx campanulate, the lanceolate acuminate teeth half the length of the tube; corolla purple, about 9 lines long, twice longer than the calyx: pod inflated, membranous, 2-celled, sessile, broadly ovate, acuminate, densely white-villous, 9 lines long. — At Fort Wingate, New Mexico; collected by Dr. W. Matthews, U. S. A. Allied to *A. Bigelovii.*

ASTRAGALUS (HOMALOBUS) WINGATANUS. Near *A. multiflorus*, scarcely 6 inches high, somewhat canescent with appressed pubescence: leaflets 4 to 6 pairs, narrow, glabrate: calyx short and shortly toothed; corolla purplish, 3 lines long: pod as in *A. multiflorus* but sessile, obtuse or somewhat narrowed at base, rather more acute at the apex. — At Fort Wingate, New Mexico (Dr. W. Matthews, 1882); collected in New Mexico also by Dr. E. Palmer in 1870 (14 and 61).

ASTRAGALUS HYPOXYLUS. Perennial, with a prostrate branching woody base and short slender herbaceous branches: leaves glaucous, canescent with a fine appressed pubescence; leaflets 4 to 6 pairs, obovate to oblong-obovate, obtuse, 1 to 3 lines long; stipules distinct, triangular-ovate: peduncles slender, exceeding the leaves (3 inches long); racemes short and close: calyx-teeth narrow, equalling the short-campanulate tube; corolla 3 lines long: pod sessile, chartaceous, oblong and turgid, sulcate on the back and 2-celled by the intrusion of the dorsal septum, 3 or 4 lines long. — Collected at Maloney's Ranch, in the Huachuca Mountains, Southern Arizona, by J. G. Lemmon, in July, 1882. Allied to *A. Cobrensis* and *A. Arizonicus.*

SPIRÆA (FILIPENDULA) OCCIDENTALIS. An herbaceous perennial, 2 to 6 feet high, the simple stem glabrous or nearly so: leaves appressed-silky on the veins beneath, 5–7-lobed, the lobes acute or acuminate, doubly lacerate-toothed, the petiole with 1 to 5 pairs of reduced ovate to narrowly lanceolate toothed leaflets; stipules broad: inflorescence a compound cymose panicle, pubescent with short somewhat appressed hairs: petals white, elliptical, sessile, 2 or 3 lines long: carpels about 9, erect, narrowly lanceolate, long-stipitate, beaked by the elongated style and villous (especially on the margin) from the summit of the style to the base. — Rocky banks of the Trask River, Tillamook County, Oregon; discovered by T. Howell and L. F. Henderson, in July, 1882. Near *S. Kamtschatica*, Pall., from which it differs in its pubescence, more developed petiolar leaflets, sessile petals, longer styles, and more villous carpels.

Ribes ambiguum. Intermediate between *R. Menziesii* and *R. Lobbii*, having the spinose fruit of the one and the obtuse anthers of the other. Glandular-pubescent and villous, especially on the petioles and peduncles: leaves larger, 1 to 2 inches in diameter; stipular spines rather short: flowers smaller, the calyx 3 or 4 lines long above the ovary, greenish, more or less villous: stamens equalling or scarcely exceeding the white petals, the light-colored anthers very small, obtuse, smooth: fruit densely covered with long spines. — On Scott Mountains, Northern California, at 8,000 feet altitude, trailing over rocks, with the flowers very villous (Rev. E. L. Greene, August, 1876); on Mount Adams, Washington Territory, at 5,000 feet altitude (W. N. Suksdorf, 1882).

Sedum radiatum. Stems from a branching rooting caudex, decumbent at base, 3 to 6 inches high: leaves oblong to oblong-ovate, obtuse or only acutish, somewhat clasping by the narrower base, 3 to 6 lines long, delicately nerved when dry: flowers sessile; sepals short and triangular; petals yellow, narrowly lanceolate, acuminate, 3 lines long: carpels broad and with the beaks abruptly divergent and horizontal in fruit. — In the Coast Ranges of California; on Gavillan Peak, Monterey County (742 Brewer); Sonoma County (J. W. Congdon); Trinity County (V. Rattan); Mendocino County (6566 Bolander). Resembling *S. Douglasii* (for which it has been mistaken, and which has not yet been found in California), but with very different foliage. This is the fourth species of the group with divaricately beaked carpels.

Gayophytum pumilum. Closely resembling low forms of *G. racemosum*, 6 inches high or less, glabrous or very nearly so, and somewhat strict: flowers less than a line broad: capsule erect, very shortly pedicellate, 6 lines long by half a line broad or more, the numerous seeds oblique in the cells. — From San Bernardino County, California, to Washington Territory; collected by Dr. Torrey, Kellogg, Lemmon, Parry, Rattan, and Suksdorf. In *G. racemosum* the capsules are more narrowly linear, usually fewer-seeded, and the seeds erect or nearly so.

Eryngium discolor. Stem erect, very slender (2 feet high), simple and monocephalous, or rarely sparingly branched: radical leaves long-petiolate, oblong to narrowly oblanceolate, thin, slightly crenate; the cauline few, sessile, linear-lanceolate, acutely or spinosely toothed: head oblong-ovate (about 6 lines long), shorter than the 10 or 12 linear-lanceolate bracts, which are white above and green beneath, with a single spinose tooth on one or both sides; head crowned with 3 or 4 similar bracts; floral bracts very narrow and spinosely acuminate. — At Cienega in the Huachuca Mountains, Southern Arizona, growing in water; J. G. Lemmon, September, 1882. Allied to *E. Mettaueri*, Wood.

SUÆDA MINUTIFLORA. Perennial (?), glabrous, the herbaceous stems erect, 2 feet high, the branches mostly short and suberect: leaves linear, not narrowed at base, 1 or 2 inches long, the upper broader and clasping at base; flower-bracts lanceolate to deltoid: inflorescence mostly crowded, the very small flowers clustered in the axils; perianth mostly scarious, not appendaged: seed less than half a line broad. — At Santa Barbara, abundant in a marsh near the sea, first collected by Mrs. Elwood Cooper, in 1879; also at Los Angeles, by Rev. J. C. Nevin, 1882.

ERIOGONUM SHOCKLEYI. Closely allied to *E. Kingii*, dwarf and very densely cespitose, densely tomentose throughout: leaves oblanceolate and petiolate, 6 lines long or less: scapes less than an inch high: heads globose, compact; involucres tomentose, scarious at base, the lobes herbaceous: flowers included, rounded at base, pubescent or nearly glabrous below, villous within, the narrowly oblong segments white with a green midvein; filaments and elongated styles exserted. — At Candelaria, Esmeralda County, Nevada, on bare rocks at 6,500 feet altitude; discovered by W. H. Shockley, June, 1882. Differing from *E. Kingii* in its shorter peduncles, more compact globose heads, smaller included flowers, narrower perianth-segments, more elongated styles, and less sharply angled akenes.

ERIOGONUM HAVARDI. Perennial, with a very short branching caudex: leaves all at the base, oblong-lanceolate, acute or acuminate, petiolate, densely tomentose beneath and silky above, 1 to 1½ inches long: peduncles slender, 1 or 2 feet high, glabrous, sparingly dichotomous above; bracts small and ternate: involucres solitary, long-pedicellate, or sessile at the forks, broadly turbinate and nerved, with short erect teeth, somewhat pubescent or glabrate, a line long or more: perianth densely silky, with narrow acute lanceolate segments, a line long, yellowish: akene glabrous, ovate, acuminate, a line long. — Collected in the Chenati Mountains, Western Texas, by Dr. V. Havard, U. S. A., 1882. An anomalous species, resembling *E. lachnogynum*, but with the reduced strictly ternate bracts of the subgenus *Ganysma*, smoother involucres, narrower perianth-segments, and glabrous akenes.

EUPHORBIA (ZYGOPHYLLIDIUM) PLUMMERÆ. Erect and slender, from a subglobose or fusiform tuberous root, dichotomously branched, puberulent, about a foot high: leaves opposite, the lowest oblong, the rest linear, an inch long by 1 or 2 lines wide, abruptly narrowed to a short slender petiole; glandular stipules obsolete: involucres mostly solitary, narrowly campanulate, half a line long and about equalling the pedicels; lobes quadrate, inflexed, lacerate; gland-appendages half as long as the involucre, rounded, entire: styles slender, united at base, bifid: capsule glabrous, depressed, 2½ lines broad: seeds globose, without caruncle, smooth and dark-colored with a thin lighter-colored scurfiness, a line in diameter. — On the "Sentinel" in Tanner's Cañon, Huachuca Mountains, Southern Arizona; collected by J. G. Lemmon and Mrs. S. Plummer Lemmon, July, 1882 (n. 2874). Closely resembling forms of *E. biformis* (see page 151), excepting in the slender styles, the larger capsules, and different seeds.

MICROSTYLIS PURPUREA. Stem a foot high, with an obtuse purplish sheath at base and a single clasping acutish oblong-ovate to oblong leaf, 3 inches long: raceme elongated, at length loosely flowered; pedicels 1 to 1½ lines long: flowers small, purple, the linear-oblong sepals 1½ lines long and exceeding the linear petals; lip triangular-lanceolate, slightly auricled at base: capsule round-ovate, about 2 lines long, exceeding the pedicels. — In Tanner's Cañon, Huachuca Mountains, Southern Arizona; J. G. and S. P. Lemmon, July, 1882 (n. 2881).

MICROSTYLIS CORYMBOSA. Stem 6 to 8 inches high, with 1 or 2 obtuse greenish sheaths at base, and a single acute or acutish clasping cordate-ovate leaf, 2 to 4 inches long: raceme contracted (½ to 1 inch long), the pedicels 3 or 4 lines long, becoming in fruit 6 lines long: flowers pale greenish yellow, the oblong acutish sepals 1½ lines long, exceeding the very narrowly linear sepals; lip broadly cordate, rather abruptly long-acuminate, not auricled at base, thin: capsule oblong-ovate, 3 or 4 lines long. — In the same locality; J. G. Lemmon, July, 1882 (n. 2882).

ALLIUM PLUMMERÆ. Bulb oblong, rhizomatous: leaves flat, linear, 2 or 3 lines wide, nearly equalling the scape, which is a foot high or more: umbel erect, few-flowered; bracts 2, long-acuminate, an inch long and equalling the slender pedicels: corolla white, the lanceolate acute segments 4 lines long, slightly exceeding the stamens: capsule prominently crested. — In the same locality and by the same enthusiastic and indomitable collectors (n. 2893).

BOUTELOUA (POLYODON) TEXANA. Perennial, densely cespitose, glabrous or loosely villous, the culms erect or geniculate at base, ½ to 1 foot high: leaves shorter than the culms, flat or revolute, sometimes pubescent on the upper surface: spikes 5 to 10, secund, cuneate, about 6 lines long with the awns; spikelets 4 to 6, crowded on the very short rhachis: glumes short-villous or pubescent on the back, very unequal, the lower bifid and the midnerve produced into an awn; flowering glume 3-awned and with a broad tooth on each side of the middle awn; sterile flowers 2 or 3, consisting of more or less similar 3-awned glumes. — Frequent from Arkansas to Western Texas (1535 Berlandier; 340 and 374 Drummond; 732 Lindheimer; 752 Wright; 771 Hall, distributed as *B. affinis*); collected also by Reverchon and others. It appears to be the *Ægopogon rigidisetus* of Steudel, and is perhaps the "*Atheropogon affinis*, Fournier," mentioned by Bentham.

INVESTIGATIONS ON LIGHT AND HEAT, PUBLISHED WITH APPROPRIATION FROM THE RUMFORD FUND.

XI.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

ON THE HEAT PRODUCED IN IRON AND STEEL BY REVERSALS OF MAGNETIZATION.

BY JOHN TROWBRIDGE AND WALTER N. HILL.

Presented May 29th, 1883.

THE object of our investigation was to determine whether the heat which is generally attributed to rapid magnetizing and demagnetizing is really due to this cause, or to induction currents in the mass of the iron. Our work, however, had in the beginning a more practical object. Since cylinders of iron and steel are heated when they are made the cores of electro-magnets, and are submitted to the effects of rapidly alternating currents, it was thought that they might exhibit different degrees of heating, and therefore that a process of determining the character of iron and steel might be based upon the phenomena observed, which could be called an electro-magnetic criterion of certain physical properties of these metals. It is well known that chemical analyses of steel and iron throw very little light upon their physical properties, such as tenacity and elasticity in general. There is no satisfactory test for the properties of different steels save by a testing-machine, and this is not readily applicable in many cases. If a method could be devised which depended simply upon electrical and magnetic phenomena, it would be a valuable aid to the metallurgist.

The amount of sulphur, of phosphorus, and other ingredients besides iron, is very small in steel, and it could hardly be expected that their presence or absence could be detected by the difference of heat developed under the influence of alternating currents, unless this heating is really due to molecular agitation produced by magnetization and demagnetization. If the heating is due to alternating induction currents in the mass of metal, there should be very little difference in the amount of heat developed by different specimens of steel; for their electrical resistance would not differ sensibly from the presence or absence of a fraction of one per cent of phosphorus or sulphur. If the heating is due to magnetization or demagnetization, and to an actual twisting of small magnets in their beds, then the molecular arrangements consequent upon different admixtures of various ingredients might produce more heat in one specimen than in another, and thus afford a criterion of the character of the steel.

We therefore determined to try our experiments on a practical scale, — to employ a powerful alternating dynamo-electric machine, and to submit the specimens of iron and steel, in a very strong magnetic field, to the alternating currents, in order to develop a large amount of heat in a short time. The dynamo-machine was of the Wilde type, and made six thousand reversals of current per minute. The currents were passed through a dynamometer, — which is described in the Proceedings of the American Academy of Arts and Sciences, 1878–79, p. 122, — and also through the coils in which the specimens were placed. A simple arrangement of keys enabled us to throw the coil, enclosing the specimen, into the circuit, and to withdraw it, — the current passsing continuously through the dynamometer. The latter instrument gave deflections which were proportional to the strength of the currents employed, and to the amount of work done in heating the iron specimens, although the absolute strength of the currents could not be determined without a calculation of the self-induction of the coils and of the dynamo-machine. The specimens of iron were immersed in a cylindrical copper calorimeter filled with mercury, and the space between the walls of the calorimeter and the surrounding coil was packed with infusorial earth, which is a very good non-conductor of heat. The duration of each experiment was one minute. In this time the strength of the current was observed, and the rise of the thermometer was ascertained. During the space of one minute the coil employed did not heat perceptibly. In two minutes, however, the coil was heated, and it was therefore determined to limit the time of the experiments to one minute, and to take the rise of temperature during that period. The amount of mercury and the pieces of iron were carefully weighed, with a view of using the data quantitatively; but the subsequent experiments showed that this was impossible, for the heating effort was confined to the outer layer of the iron, and the temperature at the centre of the bar was very much less than that at the exterior.

In the following table the first column contains the number of the iron, and opposite the number is the analysis. The third column contains the weights of metallic cylinders employed. The fourth column gives the current when one coil — called green for convenience — was used; the fifth column gives the temperature for this coil; the sixth, the current for another coil, — red coil; and the seventh, the temperature for the latter coil.

No.	Manganese.*	Weight.	Current.	Temperature.	Current.	Temperature.
			Green.	C°	Red.	
14	0.493	1398.12	9.05	17.27	11.10	17.00
32	0.584	1359.65	9.15	16.60	10.45	17.10
11	0.282	1363.00	9.15	17.66	10.00	13.05
83	0.014	1363.10	8.31	15.00	10.46	16.00
113	0.015	1358.10	8.46	15.00	10.46	16.30
231	0.020	1364.55	9.46	13.30	10.20	13.94
115	0.031	1362.57	8.10	15.00	10.49	15.10
107	0.032	1391.90	8.15	16.00	10.37	15.70
	Total Carbon.†					
83	1.044	1363.10	8.31	15.00	10.46	16.00
119	1.142	1366.70	7.46	14.80	9.43	13.80
120	1.318	1370.63	8.14	13.00	9.46	13.77
112	0.873	1363.00	8.53	17.20	11.10	17.00
113	0.923	1358.10	8.46	15.00	10.40	16.30
115	0.946	1362.57	8.10	15.00	10.49	15.10
104	0.294	1391.65	9.05	16.55	10.55	16.27
106	0.301	1394.17	8.55	16.55	10.37	13.55
231	0.009	1364.55	9.46	13.30	10.20	13.94
230	0.463	1435.12	8.33	14.40	8.33	12.10
121	0.257	1346.52	7.50	14.70	9.28	14.00
	Combined Carbon.‡					
11	1.142	1363.00	9.15	17.66	10.00	13.05
12	1.244	1363.55	9.16	17.66	11.07	16.27
83	1.024	1363.10	8.31	15.00	10.46	16.00
118	1.079	1358.62	7.50	15.33	8.56	
119	1.112	1366.70	7.46	14.80	9.43	13.80
120	1.285	1370.63	8.14	13.00	9.46	13.77
6	0.846	1370.80	9.23	17.83	10.05	13.94
38	0.012	1349.00	8.50	16.40	10.15	17.16
37	0.042	1349.90	8.55	17.90	10.30	16.20
45	0.116	1336.18	10.55	17.60	11.25	17.70
33	0.135	1399.00	9.00	17.05	11.07	16.70
122	0.383	1394.80	7.40	15.30	9.18	14.30
	Phosphorus.§					
36	0.315	1349.00	8.50	16.40	10.15	17.16
32	0.138	1359.65	9.15	16.60	10.45	17.10
33	0.113	1399.00	9.00	17.05	10.15	17.16
37	0.109	1349.90	8.55	17.90	10.30	16.20
50	0.104					
6	0.019	1370.80	9.25	17.40	10.05	13.94
1	0.014	1355.67	7.40	13.00	10.03	13.83
121	0.014	1346.52	7.50	14.70	9.28	14.00
83	0.013	1363.10	8.31	15.00	10.46	16.00

These results show that this method affords no criterion of the physical properties of iron and steel. The molecular structure of the various specimens employed was not sufficiently modified to enable us to determine any differences in molecular heating, — if the heat developed by magnetizing and demagnetizing is due to molecular heating. If it is due entirely to induction currents in the metals, the slight changes in electrical resistance produced by small quantities of sulphur, of phosphorus, and of carbon would be inappreciable in the masses of iron which we used, and we should expect to obtain under the same conditions the same rise in temperature for the different specimens of steel. Our previous work* on cobalt and nickel must therefore have been affected by some error.

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* Different proportions of manganeses give no result.

† Total carbon, — no difference.

‡ Apparently, the less carbon, the greater heat.

§ No conclusion. If any effect, phosphorus does not determine it.

We next determined to ascertain if the heating was confined to the surface of the metallic cores. Theory indicates this to be the case, whether we adopt the hypothesis that the heat is due to magnetization and demagnetization, or the hypothesis that it is produced by induction currents. We could not find, however, any experiments upon this point. The bars were prepared as follows. Each one was bored one half its length. At the outer end of the hole a shoulder was turned in order that a short piece of glass tubing could be cemented in. One thermometer was placed in the mercury surrounding the bar of iron, and another was hung in the hole in the centre of the bar, the hole being also filled with mercury. It was difficult to distinguish between the conduction of heat and the evolution of heat. The rise of temperature indicated by the inner thermometer, however, was probably entirely due to conduction of heat, as can be seen by comparing the amounts of mercury surrounding the two thermometers.

The following table exhibits the results obtained. In the third column an arbitrary designation is given to the electro-magnetic coils which were used in the experiments.

No. of Exp.	No. of Iron.	Kind of Coil.	Weight of Mercury on outside of Iron.	Weight of Mercury in cavity of Bar.	Thermometer in outer Mercury.		Thermometer in Mercury in cavity.	
					Before passage of Current.	After passage of Current.	Before passage of Current.	After passage of Current.
			Grammes.	Grammes.				
11	1	Red.	3317.9	39.07	10.7	23.0	10.5	21.5
12	12	"	"	"	13.0	26.5	12.5	24.0
13	36	Green.	"	"	13.1	27.3	13.0	25.0
14	32	"	"	"	16.0	31.0	15.5	28.0
15	113	"	"	"	16.0	31.0	15.5	28.0
16	108	"	"	"	16.8	32.0	16.2	30.0
17	1	"	"	"	21.0	34.5	20.5	32.0
18	12	"	"	"	21.5	36.0	21.0	32.5

Weights in Grammes.	36	1320.7	108	1336.0	The weights differ from the previous ones of same bars, as some metal has been bored out of the centres.
	32	1332.0	1	1323.4	
	113	1328.6	12	1335.0	

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* Proceedings of the American Academy, 1878–79, p. 114.

If the heating is due to molecular movements produced by magnetizing and demagnetizing, — and the musical note is adduced as an evidence of this, — the bar would vibrate as a whole, and would become heated throughout on account of this vibration. It is difficult to conceive how the surface action of magnetism can communicate vibrations to a solid bar of iron one inch and a half in diameter. If the bar vibrates as a whole, a certain amount of heating of the bar takes place throughout its interior. The heat in the interior of the bar, however, must be less than that at the exterior, where the magnetization exists in full strength. We believe, however, that the musical note is due to a forced vibration in the coil of the electro-magnet, — possibly due to electro-magnetic attractions; for the note can be heard when the iron core is removed, and is stronger when the core is in place simply because the magnetic field is strengthened.

The appearance presented by iron filings strewn upon the pole of a straight electro-magnet, which is submitted to the action of an alternating current, shows very strikingly the fact that it takes time to magnetize, and that magnetism resides upon the exterior of electro-magnets. Under the influence of strong currents alternating six thousand times a minute, the electro-magnet is still capable of attracting an armature with great force. The filings arrange themselves as a narrow fringe or ring upon the circumference of the end of the cylindrical bar constituting the core of the electro-magnet, leaving the surface of the end of the cylinder entirely free from filings. If filings are scattered upon this free portion of the surface, they waltz to the circumference. The fringe of iron filings vibrates in unison with the alternating currents.

In connection with this investigation, it may be interesting to refer to some experiments made by Lt.-Comm. A. G. Caldwell, U. S. N., and ourselves, on demagnetization. These experiments were made in 1880, but have not been published.

Perfect demagnetization, or entire absence of magnetism in a mass capable of magnetism, is a condition of great rarity. Approximate demagnetization has been brought about with some difficulty, but delicate tests would show traces of polarity.

We have, however, discovered a method by which complete demagnetization may be rapidly and easily produced. The principle involved is the setting up of a state of powerful magnetic vibration, by which all previous magnetic conditions are obliterated, and on the subsidence of which no polarity remains. This state of vibration is induced by an alternating current of *sufficient strength.* By this an effect is induced in the magnetized mass which can only be compared to a vibration or wave. The reversals of the inducing current cause corresponding reversals of polarity in the body acted on, and as these reversals are continuous and very rapid (5,000 to 6,000 per minute, for example), a molecular vibration probably arises. It is probable that a condition of strain or set is one of the phenomena of magnetism.

The particles have been made to assume a certain definite or polar relation or position. When, however, a powerful movement or vibration is caused, it is evident that when this vibration has become complete, — that is, involving the whole mass, — all previous conditions of strain or "permanent set" will be overcome. It must be remarked that, in order to perfectly attain this result in all cases, the exciting force must be sufficient.

When the alternating current ceases, the body acted on is left perfectly free from polarity. It is, however, in a state of extreme sensitiveness, and must be allowed to remain at rest for a short time. If it is placed north and south, it will assume polarity, and very strongly, if struck with a hammer when held in the position of the dip.

Demagnetization requires but a short time in most cases, — from one to three minutes if the current is properly adjusted. There are several ways of performing the experiment, but it will be sufficient at this time to refer to a few of them. The most effective method is to enclose the mass to be demagnetized in a coil of such a length that the whole body will occupy an approximately central position. The coil may be a simple one, in which case it must stand east and west, and before removing the object the electric machine must be stopped, and the current allowed to die away. Also, when the object is taken out of the coil, it must be carefully shielded from the earth's induction. Or the coil may be so constructed that it can be opened or divided at the centre without breaking circuit, and then the object can be taken out without stopping the alternating current. One of the coils we used was made of No. 12 copper wire, wound as one coil, but in halves, with an elastic connection. It is well known that, with an alternating current, self-induction in the coil materially reduces the current, and therefore the coil should be one of a comparatively small number of turns.

Demagnetization of small masses, not too retentive of magnetism, may be performed by placing them on the end of a bar contained in the coil, which is a part of the alternating circuit. A bar of low steel, somewhat longer than the coil, was used, and the small objects placed on its projecting end.

Perfect demagnetization is attained with varying difficulty. Ordinarily, it is rapidly and easily accomplished. Sometimes a longer time is required, or a more intense action. In numerous experiments, we derived the alternating current from a Wilde machine which gave about 6,000 reversals per minute. This rate is probably greater than is required or desirable, except in extreme cases. About 3,000 to 4,000 reversals would be a better general rate, although of course the operator should arrange his apparatus so that he could get more reversals if necessary. Failure will result if the speed is too great, as might be expected if the view here taken is correct. Usually, it will be more convenient to employ, instead of an alternating machine, a battery with a reverser arranged for varying speeds.

One application of this method is to the demagnetization of watches. Watches strongly magnetized are completely demagnetized by one to three minutes' exposure in the coil. Frequently unsuspected traces of magnetism cause annoying irregularity of action of a watch. This method enables us entirely to remove this difficulty.

Some very curious and interesting results were obtained by experimenting with magnetite.

A specimen of very pure magnetite, from North Carolina, showing marked magnetic properties, was completely demagnetized by a somewhat long exposure to the action of an alternating current applied as described above. Before demagnetization the piece had shown consequent points, although in general it possessed polarity. After treatment it attracted either end of a very light suspended needle indifferently, and when any part of the mineral was presented, just as a piece of soft iron would do. The demagnetized specimen was then placed across the poles of an electro-magnet excited by a strong current from a Gramme machine. It became strongly magnetic, with distinct poles, and without the consequent points it at first had. After this it was treated like an ordinary bar magnet, and magnetized or demagnetized at will.

Another more impure piece was originally less strongly magnetic, and was demagnetized with great difficulty. At first it displayed no general polarity, having consequent points irregularly distributed. After demagnetization it received induced magnetism and became polar, but it was a much feebler magnet than the previous specimen. Demagnetization was afterward performed more easily than at first.

A still more impure specimen was treated, but with the means at hand it was not *perfectly* demagnetized, although so nearly was this done that only traces of magnetism were noticeable.

The results of our work can be stated as follows: —

1. The heat developed by reversals of magnetization is probably due to induction currents, and not to molecular vibrations; for considerable changes in the molecular structure of different specimens of iron and steel fail to show differences in the amount of heat developed.

2. The heating of iron cores of electro-magnets, which are submitted to alternating currents, is confined to the surface until conduction equalizes the heat of the cores.

3. The musical note emitted by the core is the note of the coil, due to the number of reversals of the machine, and is merely strengthened by the metallic core of the electro-magnet. This note should not, therefore, be used as an argument in favor of molecular vibrations of magnetic particles.

4. Experiments on demagnetization confirm what has long been known in regard to the effect of vibrations and shocks upon the magnetic condition of iron and steel. They do not invalidate our results upon the heat produced by reversals of magnetization; for a very slight change in position of the molecules might affect the magnetism of a bar, and yet be insufficient to produce the great heating observed in the armatures of dynamo-electric machines.

INVESTIGATIONS ON LIGHT AND HEAT, PUBLISHED WITH APPROPRIATION FROM THE RUMFORD FUND.

XII.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

ON THE HEAT PRODUCED IN IRON AND STEEL BY REVERSALS OF MAGNETIZATION.

BY JOHN TROWBRIDGE AND CHARLES BINGHAM PENROSE.

Presented May 29th, 1883.

THE following experiments were made with the object of testing certain deductions that seem to follow from Weber's theory of magnetism. The test applies to any theory which regards magnetization to be due to a regular change of position or rotation of the molecules. Weber's theory, doubtless, has strong experimental evidence in its favor, such as the experiments of Beetz,* showing a maximum intensity of magnetization in iron deposited by electrolysis in a magnetic field. But the experiments of Siemens † indicate that the theory must at least be modified; and our experiments upon the heat developed by rapid magnetization and reversals of magnetization seem to show that molecular work — at least of the kind supposed by Weber — does not play so strong a part in magnetic phenomena as has generally been supposed.

Various observers have measured the heat which they supposed to be due to magnetization and to reversals of magnetization. Thus Joule‡ revolved a piece of iron, contained in a tube of water, between the poles of a horseshoe magnet, and measured the rise of temperature and the work done. Van Breda § placed an iron cylinder in a coil of copper wire, bored a hole in the iron, and placed the bulb of a spirit thermometer in this hole. On passing a continuous current of electricity through the coil, no increase of temperature was denoted by the thermometer. When, however, the current was made and broken thirty times a second by an interruptor, the thermometer showed a marked rise in temperature. Grove * surrounded a horseshoe electro-magnet with water at a constant temperature, placed a thermo element upon the armature, which was carefully covered with flannel, and found an increase of temperature upon interrupting or reversing the electrical current. He found no effect in non-magnetic metals. Villari † endeavored to show the same effect from transversal magnetism, by passing an interrupted current through two wires, one of lead, and the other of iron or steel. These wires were bent in the middle, placed in glass cylinders, so that their ends projected through corks at each end of the cylinders. The glass cylinders were filled with absolute alcohol, and were provided with capillary tubes, and thus served as spirit thermometers. The cylinders were placed parallel to each other. The circuit was arranged so that the interrupted current preserved always the same direction in the lead wire, while at each interruption it was reversed through the iron or steel wire. The lead wire showed no increase of heat, while the iron wire exhibited a marked rise of temperature. These various experiments can be explained on the theory that the heating is due to induction currents generated in the mass of the iron by its sudden introduction into a magnetic field. And the effect is greater in the iron and steel than in non-magnetic metals, from the reason that the coefficient of induction is very greatly increased by the substitution of an iron core in an electro-magnet for a non-magnetic core.

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* Pogg. Ann., cxi., 1860.

† Ann. Phys. Chem., 1881.

‡ Phil. Mag., xxiii. 263, 347, 435, 1843.

§ Compt. Rend., xxi. 961; also, Pogg. Ann., lxviii. 552, 1846.

It is claimed by some investigators, however, that the heating is due to a greater degree to the moving or twisting of the molecules of the iron in their beds while under the influence of the alternating and magnetizing currents. Indeed, this view is apparently held by the observers whose experiments we have quoted. And a late paper, by W. Siemens ‡ leads the reader to infer that the internal friction among the molecules of the iron contributes largely to the heating due to reversals of magnetism. The phenomena which support the view that the heat observed when a bar of iron or steel is magnetized and demagnetized is due to molecular action, are the following. The bar gives forth a musical note, which is attributed to longitudinal vibrations of the bar. A bar of steel is lengthened when magnetized. Magnetic filings distributed upon the poles of the electro-magnet move tremu-

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* Phil. Mag., xxxv. 153, 1849; Pogg. Ann., lxxviii. 567.

† Nuovo Cimento, Ser. II., Vol. IV., Nov.-Dec., 1870.

‡ Ann. der Physik und Chemie, No. 12, 1881, pp. 635-656.

lously under the influence of reversals of magnetism, and it is supposed that the particles of the entire mass of the iron partake more or less of this movement. A musical note, however, is given forth by the coil of the electro-magnet before the iron core is inserted, when an alternating current is passed through the coil. This musical note is very weak, and is greatly strengthened by the insertion of the iron core. This note can arise from the attraction of the spires of the coil, which communicate a vibrating motion to the air in the neighborhood of the coil; and this action is much increased by the inductive action caused by the insertion of the iron core.

If we accept Weber's theory, and suppose that the heat developed is due to a movement of the molecules, it follows that, if a piece of iron is alternately magnetized in different directions, the movement of the molecules, and the resultant heat, must be proportional to the angle between the directions of magnetization. Our experiments were made to test this conclusion.

A circular disk of soft iron was placed between the poles of two electro-magnets. A current was passed alternately through the magnets. The rise of temperature of the disk, after a certain time, was measured, when the axes of the poles were in the same straight line, and when they were inclined to each other at an angle a little less than 90°. According to the general theory, the heating should be less in the latter case.

Two disks cut from different pieces of soft iron were used. The diameters were respectively 2.7 cm. and 1.3 cm.; the thickness, 0.1 cm.

In order to make the magnetic field of the same strength in the two positions of the magnets, shunts of suitable resistance were applied to the circuits when the axes of the magnets were in line. The intensity of the field of each magnet was measured, in the two positions, by rotating a coil of fine wire. The arrangement of the shunts was found to answer perfectly; the intensities being unaltered by change of position. In the first series of experiments this precaution was neglected, and there was consequently a greater heating effect in one case than in the other.

The arrangement for reversing the direction of magnetization consisted of a large disk of cherry wood, 91.5 cm. in diameter, and 5 cm. in thickness. Around the circumference of the disk were fastened, at equal distances apart, 104 strips of sheet brass, 1.35 cm. wide. The disk was placed upon one end of an axle, the other end of which carried an iron wheel about 60 cm. in diameter. The iron wheel could be turned by a handle fastened to one of the spokes. All the brass strips were connected by a double copper wire with the axle. Upon the circumference of the wooden disk pressed two brushes of spring brass, arranged at such a distance apart, one above the other, that they were never simultaneously in contact with a brass strip. Each brush consisted of two pieces of brass 2.2 cm. wide. Across the axle was placed a strip of brass, held always in contact with the axle by two wires attached to the table. One of these wires was connected with one pole of the battery. The other pole was connected with the two magnets, and each brush was connected with one of the magnets. It is obvious that, by this arrangement, rotation of the disk would cause the current to pass alternately through each magnet. In the battery circuit was included a tangent galvanometer, to show any alteration in the strength of the current. It was found that the wheel could easily be turned uniformly 100 times a minute. This obviously magnetizes the iron disk 10,400 times a minute in each direction. The molecular arrangement is consequently changed 20,800 times a minute.

The elevation of temperature in the iron disk was measured by means of a thermo-electric element. A wire of German silver was soldered in the middle of one surface of the disk, and in the middle of the opposite surface was soldered an iron wire. The two wires were connected respectively with the wire from a reflecting galvanometer of six ohms resistance, and with the iron wire of another iron and German silver junction. The latter junction was placed in a glass tube, packed with asbestos, and maintained at the temperature of the room. The German silver wire of this junction was connected with the remaining wire of the galvanometer. The larger iron disk was placed perpendicular to the axis of a glass tube, which exactly fitted it; and the two wires from it were passed through corks in the extremities of the tube. The tube was placed perpendicular to the axes of the magnets, with the iron disk horizontal, and in the centre of the field. Several observations were made with the axes of the magnets in line, and with the axes inclined at an angle of about 90°. The wheel was turned for three minutes, in some cases four. At the end of this time the deflection in the galvanometer was 0.5 to 0.8 cm., and in every case the same deflection was obtained after equal times, whether the axes of the magnets were inclined at an angle of 180° or of 90°.

In the preceding experiments the glass tube was pressed against the cores of the magnets; separated from them only by a sheet of paper. It was thought that the heating of the cores by the rapid magnetization and demagnetization might be communicated to the iron disk, and thus mask the heating effect peculiar to it. That the generation of heat in the wire of the magnets had no influence was proved by passing a steady current through the magnets for several minutes, when no deflection was observed in the galvanometer. To avoid the heating effect of the cores, the smaller iron disk was placed in a glass tube which exactly fitted it, as in the preceding case. The ends of the tube were tightly closed, and it was placed in a larger tube, 2.7 cm. in diameter, parallel to the axis. A stream of water was passed through the outer tube. After several attempts, however, it was found that the water pressure was so variable that the arrangement would not answer. The larger tube was then tightly packed with asbestos, a layer of about one centimeter in thickness surrounding the smaller tube. It was thought that this arrangement would certainly prevent any communication of heat during the three minutes that the experiment lasted.

The result of this experiment was the same as before. The deflection due to the heating was unchanged by changing the positions of the magnets. The deflection was about 0.1 cm. smaller than in the preceding cases, probably on account of the smaller size of the disk.

The experiments were then repeated upon a copper disk of about the same size as the larger iron disk. No heating effect whatever was observed. It must be remembered, however, that in this case the thermo-electric element consisted of copper and German silver, the electromotive force of which is much less than that of iron and German silver.

The battery used in these experiments consisted of a modified form of Bunsen cell. The outer vessel contained dilute sulphuric acid; the inner vessel contained a solution of 150 gr. of bichromate of potash and 450 gr. of sulphuric acid to one litre of water. This cell was found to be fully as constant as the Bunsen.

The intensities of the magnetic fields were measured, after the experiments were over, by placing a small coil of copper wire before the poles and reversing the current. The current was somewhat less than when the cells were first set up.

The intensities of the magnets were respectively 2,033 and 760 times the horizontal intensity of the earth's magnetism. In the C. G. S. system the intensities were 343.57 and 128.44.

The results of the preceding experiments show that the chief heating in a mass of iron, that is alternately magnetized in different directions, is not due to molecular motion; at least, if this motion is similar to that assumed by Weber's theory.

INVESTIGATIONS ON LIGHT AND HEAT, PUBLISHED WITH APPROPRIATION FROM THE RUMFORD FUND.

XIII.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

INFLUENCE OF MAGNETISM UPON THERMAL CONDUCTIVITY.

BY JOHN TROWBRIDGE AND CHARLES BINGHAM PENROSE.

Presented May 29th, 1883.

THE following experiments were made in order to test Maggi's results [*] in regard to the effect of magnetism upon the thermal conductivity of iron. Maggi's conclusions have never been confirmed, and have been much doubted by other observers. The experiments of Sir W. Thomson,[†] in which he found that longitudinal magnetization diminished, while transverse magnetization increased the electrical conductivity of iron, afford — from the fact that electrical and thermal conductivities are in general proportional — the chief confirmation of Maggi's results. The experiments of Thomson have, however, been questioned.

In the method employed by Maggi, a circular plate of soft iron was placed horizontally upon the poles of a vertical horseshoe magnet. Through the centre of the plate passed a lead tube conveying steam. The surface of the plate was covered with a mixture of oil and wax. When the magnet was made, the melted wax was bounded by an ellipse. If the conductivity had been equal in all directions, it would have been bounded by a circle. The long axis of the ellipse was perpendicular to the line joining the two poles; the short axis was parallel to the line. The ratio of the axes was 6 : 5. The two poles were separated from the iron plate by paper. In order to compensate for the direct effect of the poles upon the flow of heat, two bars of soft iron were placed symmetrically beneath the plate, at the extremities of the diameter, perpendicular to the line joining the poles. No effort seems to have been made to avoid the effect due to the frictional generation of heat in the magnetic coil. Several other complicating causes are apparent in the arrangement which Maggi used.

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[*] Bibl. Univ. Archiv., 1850.

[†] Phil. Trans., vol. cxlvi.

A year ago we made some experiments, by a rather rough method, to find the effect of magnetism upon thermal conductivity, and obtained decidedly negative results. The same results have been obtained in the present experiments, though a much more sensitive arrangement was employed. The following method was used. A bar of soft Norway iron, 95 cm. long, 1.3 cm. wide, and 0.2 cm. in thickness, was placed horizontally through the sides of a wooden box 6 cm. wide, and 25 cm. high. The top and one side of the box were removed. 17 cm. from each end of the bar was soldered a thick German silver wire. Each projecting arm of the bar was enclosed in a glass tube 1.4 cm. in diameter. The ends of the tubes were closed with cotton. The ends of the iron bar projected slightly beyond the ends of the tubes, and were exposed to the air of the room. One arm of the bar was placed between the poles of a large electro-magnet, with its flat surface perpendicular to the axis of the magnet. The axes of the poles were in the same horizontal line, perpendicular to the bar. The tube between the magnetic poles was wrapped in a piece of thick asbestos cloth, in order to avoid complications arising from the generation of heat in the magnetic coils. The distance between the poles was about 2.5 cm. A Bunsen lamp was placed in the wooden box, and was so regulated as to maintain the iron above it at a very dull cherry-red heat. The German silver wires were connected with the wires of a reflecting galvanometer of six ohms resistance; the connections were separated by paper, bound together and covered with cloth. The lamp was always lighted from four to five hours before any observations were made. It was found that by this time the apparatus had practically reached a condition of thermal equilibrium. At first the current from a battery of ten Grove cells was used; afterwards a battery of twenty-six very large Bunsen cells was used.

After the lamp had been burning for four hours, there was always a permanent deflection of the galvanometer of about 12 cm. When the current was now passed through the magnets, this deflection was immediately changed permanently. The change was found to be due to the direct action of the magnet upon the galvanometer needle, though the distance between the two pieces of apparatus was about 10 meters. This deflection amounted to 2.8 cm. when the stronger current was used. Thirty minutes after the magnet was made, the galvanometer spot was always found to have changed by about 3 cm. The direction of the change was such as to show that the junction on the magnetized arm was becoming warmer. It was at first thought that this confirmed Maggi's results.

The apparatus was next arranged with one arm of the iron parallel to the axis of the magnet. The arm was passed through the hollow core of an electro-magnet somewhat stronger than the preceding. The same battery was used. The details of the experiment were exactly the same as when the bar was perpendicular to the lines of force. The results of several observations here also showed that the junction on the magnetized arm became hotter under magnetization.

We had previously assumed that the heat developed in the magnetic coil would be too slight to affect the iron bar. This assumption was now proved to be incorrect, by placing the unheated bar, arranged exactly as in the preceding experiments, in the magnetic field. When the magnet was made the galvanometer needle began slowly to move, always in the direction showing a heating of the junction on the magnetized arm. This deflection was slightly larger, after the same space of time, than the deflections observed in the previous experiments, and consequently rendered the results of these experiments useless.

In order to avoid complications arising from the heat generated by the electric current, the following arrangement was adopted. About 17 cm. from one end, the iron bar was bent upon itself. At the end of the bent part, and at the point of the bar opposite this end, were soldered two German silver wires. These two thermo-electric junctions were about 0.4 cm. apart, and were separated from each other by densely packed asbestos. The arm was placed in a glass tube, arranged as before. The bar was heated about 19 cm. from the thermo-electric junctions. By this arrangement the heating of the magnetic coils had an equal effect upon the two junctions, while any change, due to altered conductivity, of the flow of heat along the bar would affect the relative temperatures of the junctions. When the German silver wires were connected as before with the galvanometer, and the unheated bar was placed either parallel or perpendicular to the axis of the magnet, there was, after forty-five minutes observation, absolutely no deflection in the galvanometer. This showed that the arrangement obviated all difficulties arising from heating the coil; and, moreover, that the magnetic field did not perceptibly alter the thermo-electric relation of iron and German silver. When the bar was placed perpendicular to the axis of the magnet, thin plates of soft iron, running the length of the glass tube, were placed upon the magnetic poles, thus lengthening the field through which the bar passed. The bar was next heated as before. After several hours, the galvanometer generally showed a permanent deflection of 35–40 cm., in a direction indicating that the junction at the end of the bar was the cooler. Several observations were made, both when the bar was parallel and perpendicular to the axis of the magnet. The current was passed for about one hour, and in every case there was absolutely no change of the deflection beyond the immediate change due to the direct action of the magnet.

The result of these experiments seems conclusively to show that longitudinal and transverse magnetism — at least of the strength used — have no influence upon thermal conductivity of soft iron. It was, however, decided to try a thinner piece of iron than the preceding. A strip of ordinary tinned iron was therefore cut about 1.3 cm. wide, and was bent over and arranged exactly as before. The whole tube was packed with asbestos and cotton to avoid any motion of the strip when the magnet was made. The distance of the flame from the two thermo-electric junctions was 10 cm. A heating of ninety minutes was found to be sufficient in this case for the strip to reach a permanent condition of temperature. The deflection showing the difference of temperature between the junctions was about 13 cm. When the magnet was made, there was no change of the deflection after thirty-five minutes' observation.

The strength of the magnetic field when the bar was placed perpendicular to the lines of force was measured after the preceding experiments were made, and was found to be 10,420 times the horizontal intensity of the earth's magnetism at Cambridge. In the C. G. S. system this would be about 1,760.

Aside from the experiments of Maggi, those of Thomson upon electrical conductivity are the only experiments that seem to be directly opposed to the conclusion that must be drawn from our observations. Magnetism undoubtedly changes several physical properties of iron, but though this renders it probable, *a priori*, that the thermal conductivity might be changed, yet it does not necessitate such a change. The thermo-electric relation of iron is changed by magnetization, but the thermo-electric relation appears to be unconnected with thermal conductivity.

INVESTIGATIONS ON LIGHT AND HEAT, PUBLISHED WITH APPROPRIATION FROM THE RUMFORD FUND.

XIV.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

PAPERS ON THERMO-ELECTRICITY.—No. I.

BY JOHN TROWBRIDGE AND CHARLES BINGHAM PENROSE.

Presented May 29th, 1883.

IN general we have, if σ denote the Thomson effect and T the temperature,

$$\int \sigma \, dT = 0.$$

There are, however, certain cases in which it appears that this integral is not zero. These cases occur when an abrupt variation of temperature takes place across any plane cutting the conductor. It is well to consider the problem from several points of view. Suppose a homogeneous circuit so heated that one part is maintained at the constant temperature T, and the rest at the temperature T_0, the change of temperature taking place at two planes which cut the conductor. The Thomson effect can only take place at these planes, and it is of opposite sign at each. The only heat effect, as far as we know, in this circuit, is the Thomson effect; if there is any electromotive force, we must have

$$E = \sigma_A - \sigma_B,$$

σ_A and σ_B being the effects at the planes.

From thermodynamic principles, it is obvious that the absorption must take place at the higher temperature T, and the evolution at T_0. The second law of thermodynamics gives

$$\frac{\sigma_A}{T} - \frac{\sigma_B}{T_0} = 0.$$

This equation shows that σ_A cannot equal σ_B, and in this special case of a homogeneous circuit there must be an electromotive force. We also see that, at least for this case, the Thomson effect must be proportional to the absolute temperature.

To look at the problem from another point of view, suppose that in the homogeneous circuit there is but one abrupt change of temperature. That is, the temperature varies continuously from $T_0 - T_1$, and then falls abruptly to T_0. In this case the curve representing the change of temperature along the curve is discontinuous at T. The integral of σ throughout the circuit is then not necessarily zero. The part of the integral corresponding to the fall from $T - T_0$ has in this case the maximum or the minimum value of which it is capable. The complete effect through the circuit is represented by

$$\int_{T_1}^{T_0}\sigma + \sigma (T_1 - T_0).$$

If σ varies with the temperature, this expression cannot equal zero. If the current is in such a direction as to absorb heat at the plane of abrupt variation of temperature, the part of the general integral corresponding to the abrupt change has its maximum value; otherwise it has its minimum value. There is nothing in the equation to determine the direction of the current. Its intensity will obviously be the same in either direction,

$$\int_{T}^{T_0}\sigma\, dT$$

being a mean between its maximum and minimum values. We have tried several experiments to see if the direction of the current was related to the direction of the Thomson effect. It was soon perceived, however, that in the method employed many complicating causes masked the effect sought. From the fact that the equations show that a current can take place in either direction, we must conclude that there are most probably equal currents in opposite directions, making the resultant current equal zero. This is especially so in the perfectly symmetrical case first considered, where there are two abrupt changes of temperature. We are not aware that any experiments have been made on a circuit arranged in this way, and in fact it would be most difficult to realize the arrangement practically. In the second case, however, experiment shows that there is a current, and if there is anything in the nature of the metal which prevents the plane of abrupt variation of temperature from acting as the reservoir and refrigerator at the same time, then the equations explain the current. We shall see that in special cases there is another heat effect at this plane; it is probable, therefore, that this effect exists in every case.

An abrupt variation of temperature can be produced practically in various ways. Le Roux and others have produced the currents by cutting a strip of metal in such a shape that its section varied abruptly from the broad to the narrow part. When a flame is applied to the narrow part, it becomes heated so much more rapidly than the broad portion that the temperature changes abruptly.

Maxwell says, in regard to these cases, that a current is produced in a homogeneous conductor when "at any part of the conductor a sensible variation of temperature occurs between points whose distance is within the limits of molecular action."

Le Roux attempts to explain the phenomena by a difference of pressure caused by the heat, the current being due to heating the contact of compressed and free parts of the same metal.

Becquerel produced an abrupt variation of temperature by suddenly uniting the hot and cold ends of a wire. The current in this case is, as Becquerel pointed out, at least partly due to a coating of oxide. In the case of lead the current is probably due to a coating of oxide, as the Thomson effect for lead is zero.

In the experiments made by us, with the object of observing whether there was any law connecting the direction of the current with that of the Thomson effect, the method of varying the section abruptly was employed. This method gets rid of all complications due to impurities at the surface of contact; but in cutting the metal to the necessary shape, the parts were necessarily more or less strained, and the results sought were always masked by a permanent current between the strained and unstrained parts. The direction of this current depended upon the position of the point where the heat was applied. The direction could be reversed by moving the lamp a few centimeters to either side, beneath the narrow part. The best method to avoid these complications is to pass a fine wire through the non-conducting partition separating the two compartments of a vessel, each compartment being filled with some good thermal conductor, and kept at different temperatures. This method has not yet been tried.

We have seen that the equations do not determine the direction of the thermo-electric current, and consequently that it is probable that a current exists in both directions. The Thomson effect, then, cannot alone explain the current that experiment shows to exist; there must be some other effect at the plane of abrupt variation. That this effect does take place in certain special cases there can be no doubt.

Tables of the values of the Thomson effect show that nickel changes twice between 175° and 340°. There are two points of deflection in the thermo-electric line. At these points, —

$$\frac{d}{dT}\left(\frac{\pi}{T}\right) = 0.$$

Let T_0 be the temperature at which the Thomson effect equals zero, and let T be a temperature above this. Let the circuit be so heated that the temperature rises gradually from $T_0 — T$, and then falls abruptly to T_0. Any heat effect at the plane must necessarily take place at the higher temperature, if we suppose the Thomson effect alone to exist. Hence from thermodynamic considerations the absorption must take place here. In this case the direction of the current is completely determined.

Suppose, now, we pass a current from some outside source, through the circuit, in such a direction as to absorb heat where the temperature falls gradually. There can be no evolution of heat at the plane, as it can take place neither at T_0 nor at T. If the whole energy of the current is expended in heat we must have

$$EI = RI^2 - I\int_T^{T_0} \sigma\, dT.$$

$$\therefore\ E = RI - \int_T^{T_0} \sigma\, dT.$$

That is, the electromotive force of the outside current is diminished by an electromotive force peculiar to the arrangement, and due to the absorption of heat in the circuit. But if the Thomson effect is the only effect in this circuit, the current produced by it does not obey the fundamental principles of thermodynamics. We have an engine, working between finite temperatures, in which there is no loss of heat.

Suppose, moreover, $T < T_0$, and pass a current in such a direction as to evolve heat where the temperature varies continuously. There can be no absorption at T_0, and

$$E = RI + \int \sigma\, dT.$$

In this case the outside electromotive force is increased by a secondary electromotive force. But unless some effect besides the Thomson effect exists, the secondary current is produced alone by an evolution of heat. The conclusion is absurd, and there must exist some other effect at the plane of abrupt variation. If this effect exists for the special cases considered, it seems probable that it exists for all cases where there is a sensible variation of temperature between points whose distance is within the limits of molecular action. It obviously differs from both the Thomson and Peltier effects.

Several properties of this effect can easily be deduced. In the first place, since in general the current is caused entirely by it, — the Thomson effect producing equal and opposite electromotive forces, — if the effect obeys the ordinary thermodynamic laws, it must exist so as to cause an absorption and an evolution of heat at the plane of abrupt variation. This is not the only case of a thermodynamic arrangement where the evolution and absorption take place at one plane. In a thermo-electric circuit which has two neutral points, and in one metal of which the Thomson effect is null, if the two junctions are maintained respectively at the temperatures of the neutral points, all the heat effects take place in one metal, and if the circuit is so arranged that the change of temperature takes place across a plane, then all the effects occur at this plane.

If we call the new effect $\Phi(T)$, the general equations for a circuit where there exists one abrupt variation of temperature become: —

$$-\left[\int_{T_0}^{T_1}\sigma\, dT + \sigma_{T_1}(T_1 - T_0)\right] + \int_{T_1}^{T_0}\sigma\, dT + \sigma_{T_0}(T_0 - T_1) + \Phi(T_1) - \Phi(T_0) = E.$$

$$-\left[\int_{T_0}^{T_1}\frac{\sigma}{T}\, dT + \sigma_{T_1}\frac{T_1 - T_0}{T_1}\right] + \int_{T_1}^{T_0}\frac{\sigma}{T}\, dT + \sigma_{T_0}\frac{T_0 - T_1}{T_0} + \frac{\Phi(T_1)}{T_1} - \frac{\Phi(T_0)}{T_0} = 0.$$

The first parts of these equations are identically zero: —

$$\Phi(T_1) - \Phi(T_0) = E.$$

$$\frac{\Phi(T_1)}{T_1} - \frac{\Phi(T_0)}{T_0} = 0.$$

The latter equation shows that $\Phi(T)$ is proportional to T. The electromotive force is then proportional to the difference of temperature between the two surfaces of the plane.

The chief practical uses of thermo-electricity are in the measurement of high and low temperatures, and in the conversion of the energy of heat into that of an electric current. The measurement of temperatures is much complicated by the existence of the two thermal effects, and by the fact that the direction of these effects is not constant for all ranges of temperature. The existence of the Thomson effect renders the curve of the electromotive forces and temperatures a parabola. The electromotive force cannot be considered proportional to the difference of temperatures of the junctions. Tait's ingenious method of acting on a differential galvanometer with two elements, gives an arrangement where the deflection is proportional to the difference of temperatures; but the method is exceedingly difficult in practice. We have also seen that, when an abrupt variation of temperature is produced, the electromotive force is probably proportional to the difference of temperatures; but there is no obvious method of realizing this arrangement practically for the measurement of temperature. The chief difficulty, however, in using the thermo-electric element as a thermometer, is due to the reversal of the heat effects. Every element must first be tested through the ranges in which it is to be used; and this testing necessitates the use of some other method of measuring temperatures, which is very difficult and inaccurate.

In regard to the use of the thermo-electric element as a heat engine, there is always a loss of heat, from two causes, which is absolutely unavoidable unless some substance can be procured which has a thermal conductivity of zero, and a finite electrical conductivity. This loss must always be taken into consideration in comparing the efficiency of the thermo-electric engine with that of other heat engines.

In a bar of section S, and length l, the quantity of heat lost in unit time by conduction is

$$H = KS\frac{t_2 - t_1}{l}.$$

That generated in unit time by a current of electricity is

$$H_1 = I^2 k\frac{l}{S} = E^2 S\frac{1}{kl}.$$

K and $\frac{1}{k}$ are the thermal and specific electrical conductivities. Loss of heat by radiation from the surface of the bar is supposed to be avoided. If this bar is supposed to form part of a thermo-electric element, any increase of S throughout the bar, that is, so as to increase the surfaces of contact, will increase $H + H_1$. If, however, the current strength is fixed, that is, if the current is passed through the bar from an outside circuit of large resistance compared with that of the bar, we may consider I independent of S, and the sum of the heat lost is a minimum when

$$\frac{dH}{dS} + \frac{dH^1}{dS} = 0.$$

$$\therefore -I^2 k l \frac{1}{S^2} + K \frac{t_2 - t_1}{l} = 0.$$

$$\therefore S = Il \left(\frac{k}{K(t_2 - t_1)}\right)^{\frac{1}{2}}.$$

Substituting this value of S in H and H_1,

$$H = I[kK(t_2 - t_1)]^{\frac{1}{2}}, \quad \text{and} \quad H_1 = I[kK(t_2 - t_1)]^{\frac{1}{2}}.$$

That is, the heat dissipated is a minimum when that generated by the current per unit time is equal to that lost by conduction per unit time.

Within certain limits the thermo-electric engine follows the ordinary law of other heat engines: the work done increases as the difference between the temperatures of the hot and cold junctions increases. Unfortunately, however, the existence of neutral points renders it impossible to obtain an unlimited electro-motive force from a thermo-electric element. This appears to be one of the most serious objections to the practical use of thermo-electricity. We are at present engaged upon some experiments on the effect of high pressure and high temperature upon the position of the neutral point.

XV.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF HARVARD UNIVERSITY.

THE ELECTROMOTIVE FORCE OF ALLOYS.

By John Trowbridge and E. K. Stevens.

Presented May 29th, 1883.

The best study of alloys and the most thorough work on them has been done by Matthiessen, who proved conclusively that alloys were neither mechanical mixtures nor chemical compounds, but what he terms, in a general way, "a solidified solution of one metal in another." He also showed that, with reference to the formation of alloys, metals were divided into two classes; — the first class being those which, when alloyed with each other, give a conductivity in proportion to the respective volumes of the two metals; and the second, those which, when alloyed with each other, give a conductivity which is less than that of the respective volumes of the two metals.

The aim of this investigation has been to note the variation of electromotive force in different alloys of the same metals, and to deduce, if possible, some general law which governs the variation.

Two sets of alloys were used, — one set of lead and tin, and the other of copper and zinc. The first set was made by taking the proportional weights of lead and tin and melting them together in a crucible, and then pouring them out on a flat surface and allowing them to cool. The second set was made by melting a weighed amount of copper in a Fletcher gas-furnace, and, when in a molten state, adding more than the required amount of zinc, in order to make allowance for volatilization. Pure metals were obtained, in order that the results might be as accurate as possible.

It was deemed sufficient, as far as the lead and tin alloys were concerned, to weigh out carefully the required amounts of each metal, and to take those weights as showing the composition. This could not be done with the copper and zinc alloys, as it is impossible to determine how much of the zinc volatilizes; so with these it is necessary to resort to analytical methods of determining the per cent of each. The copper was determined by electrolysis, by precipitating the copper, from a sulphuric acid solution of the alloy, upon a platinum disk connected with the negative pole of a battery, and the positive pole dipping in the solution. The zinc was determined by subtracting the per cent of copper from a hundred per cent.

The composition of the alloys are given in the tables below, and will be referred to by number hereafter.

Number.	Alloys of Sn and Pb.		Number.	Alloys of Cu and Zn.	
	Parts by Weight of Sn.	Parts by Weight of Pb.		% of Cu.	% of Zn.
I.	1	9	I.	91.92	8.08
II.	2	8	II.	85.75	14.25
III.	3	7	III.	72.99	27.01
IV.	4	6			
V.	5	5	IV.	66.70	33.30
VI.	6	4	V.	49.32	50.68
VII.	7	3	VI.	27.99	72.01
VIII.	8	2			
IX.	9	1	VII.	7.53	92.47

Four determinations were made with these alloys, the first two being the observation of the electromotive force of each alloy, with platinum for the positive pole and the alloy as the negative pole, with Fresh Pond water as the liquid; the second two being the determination of the electromotive force with the same positive pole, but with distilled water acidulated with a small quantity of sulphuric acid for a liquid. A mirror galvanometer and ground-glass scale were used, and a large resistance placed in the circuit, and the galvanometer shunted so as to reduce the deflection.

The first two tables do not give any general law for the electromotive force of alloys, the force being especially irregular, which is perhaps due to the fact that the electromotive forces of the two metals are very nearly alike.

The explanation of the third table is rather unsatisfactory, since the sulphate of lead is insoluble, while the sulphate of tin is not known; and this last may account for the change from the first tables. In the fourth table, the increase in electromotive force of the alloys containing the more copper may be accounted for by the fact that the sulphate of copper is more readily soluble than the sulphate of zinc.

I. The electromotive force of the alloys of tin and lead, and of the metals themselves, when the resistance is 7,180 ohms, and the constant of the galvanometer .000003435.

The first column gives the deflection in millimeters; the second, the tangent of one half the angle of deflection; the third, the product of the constant by the total resistance; and the fourth, the electromotive force in volts. The liquid in this case is water.

Number.	Deflection.	Tan ½ Angle of Deflection.	E. M. F. in Volts.
Pb	207	.0953	0.238
I.	205	.0942	0.249
II.	182	.0837	0.222
III.	173	.0795	0.201
IV.	212	.0975	0.258
V.	184	.0846	0.224
VI.	216	.0993	0.263
VII.	175	.0805	0.213
VIII.	208	.0956	0.253
IX.	195	.0896	0.237
Sn	164	.0754	0.199

II. The electromotive force of the alloys of copper and zinc, with a total resistance of 19,708 ohms, the constant being the same as before, and the liquid Fresh Pond water.

Number.	Deflection.	Tan ½ Angle of Deflection.	E. M. F. in Volts.
Cu	10	.0046	0.031
I.	12	.0055	0.037
II.	17	.0078	0.053
III.	52	.0239	0.162
IV.	64	.0294	0.199
V.	106	.0487	0.330
VI.	131	.0602	0.408
VII.	218	.1002	0.678
Zn	228	.1048	0.709

The resistance of distilled water is so great, that it was impossible to get any good or satisfactory results. The addition of about one tenth of a cubic centimeter of strong sulphuric acid to about one hundred and fifty cubic centimeters of distilled water, gave the liquid used in the last two observations.

III. The electromotive force of the alloys of lead and tin, with total resistance of 22,608 ohms, the constant being the same, and the liquid as stated above.

Number.	Deflection.	Tan ½ Angle of Deflection.	E. M. F. in Volts.
Pb	185	.0881	0.661
I.	193	.0887	0.689
II.	195	.0896	0.696
III.	198	.0911	0.708
IV.	197	.0906	0.704
V.	196	.0902	0.701
VI.	194	.0892	0.693
VII.	198	.0911	0.708
VIII.	189	.0874	0.679
IX.	104	.0892	0.693
Sn	202	.0929	0.722

IV. The electromotive force of the alloys of copper and zinc, with a total resistance of 2,380 ohms, and the same constant of galvanometer and the same liquid as in the preceding determination.

Number.	Deflection.	Tan ½ Angle of Deflection.	E. M. F. in Volts.
Cu	43	.0188	0.153
I.	34	.0156	0.130
II.	40	.0184	0.150
III.	43	.0188	0.153
IV.	47	.0216	0.176
V.	55	.0253	0.206
VI.	115	.0529	0.432
VII.	203	.0939	0.768
Zn	234	.1763	1.442

It would seem to follow, from the last table at least, that in acid solutions the electromotive force of alloys is determined by the proportional part of that metal which is most readily attacked by the acid.

The general differences in the behavior of the two sets of alloys may perhaps be accounted for by the distinction which Matthiessen[*] made between the two kinds of alloys. He classes an alloy of lead and tin among those which are "solidified solutions of one metal in another," while he calls alloys, like copper and zinc, "solidified solutions of one metal in an allotropic modification of another."

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[*] British Association Report, 1863, p. 47.

XVI.

THE POTENTIAL OF A SHELL BOUNDED BY CONFOCAL ELLIPSOIDAL SURFACES.

BY FRANK NELSON COLE.

Presented May 29th, 1883.

LET there be three confocal ellipsoids, of which the outer two have their bounding surfaces fixed, while that of the inner ellipsoid approaches that of the middle one, the three surfaces always remaining confocal. Let X_{13} and X_{23} be the respective attractions, resolved parallel to the axis of x, of the inner and middle ellipsoids at any point in the surface of the outer ellipsoid; and let X_{31} and X_{32} be the attractions of the outer ellipsoid at the corresponding points of the inner and middle ellipsoids. To calculate the limiting value of $X_{23} - X_{13}$ as the inner ellipsoid approaches the middle one:—

By Ivory's theorem,

$$X_{23} = \frac{b_2 c_2}{b_3 c_3} X_{32}.$$

Also,

$$X_{32} = 2 \reflectbox{∂} \rho a_3 b_3 c_3 Q_{a_3} x_2,$$

where

$$Q_{a_3} = \int_o^\infty \frac{dt}{(a_3{}^2 + t)\sqrt{(a_3{}^2 + t)(b_3{}^2 + t)(c_3{}^2 + t)}},$$

and a, b, c, and x are the semi-axes of an ellipsoid and the x co-ordinate of a point, the subscripts denoting the ellipsoid to which the axes belong and on the surface of which the point lies.

Hence

$$X_{23} = \frac{b_2 c_2}{b_3 c_3} X_{32} = 2 \reflectbox{∂} \rho a_3 b_2 c_2 Q_{a_3} x_2 = 2 \reflectbox{∂} \rho a_2 b_2 c_2 Q_{a_3} x_3;$$

for x_2 and x_3 being co-ordinates of corresponding points, we have

$$a_3 x_2 = a_2 x_3.$$

Now

$$\begin{aligned} X = X_{23} - X_{13} &= 2 \backepsilon \rho Q_{a_3} x_3 \delta (a_1 b_1 c_1) \\ &= 2 \backepsilon \rho\, Q_{a_3} x_3 \{a_1 b_1 \delta c_1 + a_1 c_1 \delta b_1 + b_1 c_1 \delta a_1\}, \end{aligned}$$

and, since

$$a^2 - b^2 = \text{const.}, \qquad a^2 - c^2 = \text{const.}, \qquad a\delta a = b\delta b = c\delta c,$$

so that

$$\begin{aligned} X &= 2 \backepsilon \rho Q_{a_3} x_3 \left\{ \frac{a_1^2 b_1^2 + b_1^2 c_1^2 + a_1^2 c_1^2}{a_1 b_1 c_1} \right\} a_1 \delta a_1, \\ &= k Q_{a_3} x_3, \end{aligned}$$

or, dropping subscripts,

$$X = k Q_a x,$$

$$Y = k Q_b y,$$

$$Z = k Q_c z,$$

where

$$Q_b = \int_0^\infty \frac{dt}{(b^2 + t) \sqrt{(a^2 + t)(b^2 + t)(c^2 + t)}}$$

and

$$Q_c = \int_0^\infty \frac{dt}{(c^2 + t) \sqrt{(a^2 + t)(b^2 + t)(c^2 + t)}}.$$

Legendre has shown that

$$Q_a + Q_b + Q_c = \frac{2}{abc},$$

and the same result may also be obtained as follows. By the theory of potential,

$$\frac{dX}{dx} + \frac{dY}{dy} + \frac{dZ}{dz} = 0,$$

for all points external to the attracting mass. Hence

$$Q_a + Q_b + Q_c + x \frac{dQ_a}{dx} + y \frac{dQ_b}{dy} + z \frac{dQ_c}{dz} = 0.$$

Now

$$\frac{dQ_a}{dx} = \left\{ \frac{dQ_a}{d(a^2)} + \frac{dQ_a}{d(b^2)} + \frac{dQ_a}{(dc^2)} \right\} \frac{d(a^2)}{dx} = \frac{d}{d(a^2)} (Q_a + Q_b + Q_c) \frac{(da^2)}{dx};$$

and

$$\frac{2\, xdx}{a^2} = \frac{x^2 d(a^2)}{a^4} + \frac{y^2 d(b^2)}{b^4} + \frac{z^2 d(c^2)}{c^4} = \frac{d(a^2)}{p^2}.$$

$$\therefore \frac{d(a^2)}{dx} = \frac{2\,xp^2}{a^2}.$$

$$\therefore\; Q_a + Q_b + Q_c + \frac{2\,x^2p^2}{a^2}\frac{d}{d(a^2)}(Q_a + Q_b + Q_c)$$

$$+ \frac{2\,y^2p^2}{b^2}\frac{d}{d(b^2)}(Q_a + Q_b + Q_c) + \frac{2\,z^2p^2}{c^2}\frac{d}{d(c^2)}(Q_a + Q_b + Q_c) = 0,$$

for all values of x, y, and z.

$$\therefore\; Q_a + Q_b + Q_c = -\,2\,a^2\frac{d}{d(a^2)}(Q_a + Q_b + Q_c)$$

$$= -\,2\,b^2\frac{d}{d(b^2)}(Q_a + Q_b + Q_c)$$

$$= -\,2\,c^2\frac{d}{d(c^2)}(Q_a + Q_b + Q_c).$$

Integrating,

$$Q_a + Q_b + Q_c = \frac{\text{const.}}{abc}.$$

To determine this constant we must use the surface condition

$$\frac{dV_1}{d\nu_1} + \frac{dV_2}{d\nu_2} = 4\,\text{ə}\sigma.$$

The X force which the shell exerts on a point in its interior is

$$+2\,\text{ə}\rho x\delta(a_1b_1c_1Q_{a_1}) = +\,2\,\text{ə}\rho x a_1b_1c_1\delta Q_{a_1} + 2\,\text{ə}\rho x Q_{a_1}\delta(a_1b_1c_1),$$

so that the sum of the X components on the two sides of the shell is

$$2\,\text{ə}\rho x a_1b_1c_1\delta Q_a = 2\,\text{ə}\rho x abc\left\{\frac{dQ_a}{d(a^2)} + \frac{dQ_b}{d(b^2)} + \frac{dQ_c}{d(c^2)}\right\}\delta(a^2).$$

Resolving the sums of the components along the normal, we have

$$2\,\text{ə}\rho abc\left\{\frac{d}{d(a^2)}(Q_a + Q_b + Q_c)\frac{px^2}{a^2} + \frac{d}{d(b^2)}(Q_a + Q_b + Q_c)\frac{py^2}{b^2}\right.$$

$$\left. + \frac{d(c^2)}{d}(Q_a + Q_b + Q_c)\frac{pz^2}{c^2}\right\}\delta(a^2) = -\,4\text{ə}\sigma = -\,4\,\text{ə}\theta\rho,$$

where θ is the thickness of the shell and ρ is the density of the original ellipsoids.

Now
$$\theta = \frac{a\delta a}{p},$$

for, along the normal, we have

$$\frac{y\delta x}{b^2} = \frac{x\delta y}{a^2}, \qquad \frac{z\delta x}{c^2} = \frac{x\delta z}{a^2}.$$

Also

$$\frac{x\delta x}{a^2} + \frac{y\delta y}{b^2} + \frac{z\delta z}{c^2} = \frac{x^2\delta a}{a^3} + \frac{y^2\delta b}{b^3} + \frac{z^2\delta c}{c^3}.$$

$$\therefore\ (\delta x^2 + \delta y^2 + \delta z^2)^{\frac{1}{2}} = \frac{a\delta a}{p}.$$

$$\therefore\ -abcp^2 \left\{ \frac{x^2}{a^4} + \frac{y^2}{b^4} + \frac{z^2}{c^4} \right\} \frac{\text{const.}}{2\,abc} = -1.$$

$$\therefore\ \text{const.} = 2.$$

$$\therefore\ Q_a + Q_b + Q_c = \frac{2}{abc}.$$

. . . .

Let V denote the potential due to the shell on its exterior. Then

$$dV = k\,\{Q_a x dx + Q_b y dy + Q_c z dz\}.$$

Hence for all points on the ellipsoid whose axes are $2a$, $2b$, $2c$,

$$V - V_0 = \frac{k}{2}\,\{Q_a x^2 + Q_b y^2 + Q_c z^2 - Q_a x_0{}^2 - Q_b y_0{}^2 - Q_c z_0{}^2\},$$

where V and V_0 are the potentials at xyz and $x_0 y_0 z_0$, both points being on the ellipsoidal surface of which the axes are $2\,a$, $2\,b$, $2\,c$.

Now let

$$x_0 = \frac{a}{\sqrt{3}}, \qquad y_0 = \frac{b}{\sqrt{3}}, \qquad z_0 = \frac{c}{\sqrt{3}},$$

so that

$$x_0 dx_0 = \frac{ada}{3}, \qquad y_0 dy_0 = \frac{bdb}{3}, \qquad z_0 dz_0 = \frac{cdc}{3}.$$

Then

$$V_0 = \frac{k}{3}\int_\infty^a \{Q_a a da + Q_b b db + Q_c c dc\} = \frac{k}{3}\,Q,$$

where

$$Q = -2\int_0^\infty \frac{dt}{\sqrt{(a^2+t)\,(b^2+t)\,(c^2+t)}};$$

$$\therefore\ V = \frac{k}{2}\left\{ Q_a x^2 + Q_b y^2 + Q_c z^2 - \frac{a^2 Q_a + b^2 Q_b + c^2 Q_c}{3} + \frac{1}{3}\,Q \right\}.$$

Also

$$Q = 2\int_{\infty}^{a}\left\{ Q_a a\,da + Q_b b\,db + Q_c c\,dc \right\} = 2\int_{\infty}^{a}\frac{2\,a\,da}{abc} = 4\int_{\infty}^{a}\frac{da}{bc},$$

and consequently Q is a homogeneous function of a, b, c of degree —1.

$$\therefore\ a^2Q_a + b^2Q_b + c^2Q_c = -\tfrac{1}{2}Q.$$

$$\therefore\ V = \frac{k}{2}\left\{ x^2Q_a + y^2Q_b + z^2Q_c + \tfrac{1}{2}Q \right\}$$

$$= \frac{k}{2}\left\{ (x^2 - a^2)\,Q_a + (y^2 - b^2)\,Q_b + (z^2 - c^2)\,Q_c \right\}.$$

. . . .

Within the shell

$$X = +\,2\,\partial\rho x Q_{a_1}\delta(a_1b_1c_1) + 2\,\partial\rho x a_1b_1c_1\delta Q_{a_1}$$

$$= \left[+\,2\,\partial\rho Q_{a_1}\left\{ \frac{a_1{}^2b_1{}^2 + b_1{}^2c_1{}^2 + c_1{}^2a_1{}^2}{a_1b_1c_1} \right\} x - \frac{4\partial\rho a_1b_1c_1}{a_1{}^3b_1c_1}\,x \right] a_1\delta a_1.$$

$$X = +\,kQ_{a_1}x - 4\,\partial\rho\,\frac{xa_1\delta a_1}{a_1{}^2},$$

$$Y = +\,kQ_{b_1}y - 4\,\partial\rho\,\frac{ya_1\delta a_1}{b_1{}^2},$$

$$Z = +\,kQ_{c_1}z - 4\,\partial\rho\,\frac{za_1\delta a_1}{c_1{}^2}$$

$$V = \frac{k}{2}\,(x^2Q_{a_1} + y^2Q_{b_1} + z^2Q_{c_1}) - 2\,\partial\rho\left(\frac{x^2}{a_1{}^2} + \frac{y^2}{b_1{}^2} + \frac{z^2}{c_1{}^2}\right) a_1\delta a_1 + \text{const.}$$

At the surface the const.

$$= 2\,\partial\rho a_1\delta a_1 + \frac{k}{4}\,Q\,;$$

$$\therefore\ V = \left\{ \frac{k}{2}\,Q_{a_1} - \frac{2\,\partial\rho a_1\delta a_1}{a_1{}^2} \right\} x^2 + \left\{ \frac{k}{2}\,Q_{b_1} - \frac{2\,\partial\rho a_1\delta a_1}{b_1{}^2} \right\} y^2$$

$$+ \left\{ \frac{k}{2}\,Q_{c_1} - \frac{2\,\partial\rho a_1\delta a_1}{c_1{}^2} \right\} z^2 + 2\,\partial\rho a_1\delta a_1 + \frac{k}{4}\,Q.$$

The equipotential surfaces within the shell are quadrics, and it is easily seen that they are hyperboloids. For if a, b, c denote their semi-axes, we have

$$\frac{1}{a^2}+\frac{1}{b^2}+\frac{1}{c^2}=\frac{k}{2}\left\{Q_{a_1}+Q_{b_1}+Q_{c_1}\right\}-2\,\partial\rho a_1\delta a_1\left\{\frac{1}{a_1^{\,2}}+\frac{1}{b_1^{\,2}}+\frac{1}{c_1^{\,2}}\right\}$$

$$=2\,\partial\rho\left[\left\{\frac{a_1^{\,2}b_1^{\,2}+b_1^{\,2}c_1^{\,2}+c_1^{\,2}a_1^{\,2}}{a_1^{\,2}b_1^{\,2}c_1^{\,2}}\right\}-\left\{\frac{a_1^{\,2}b_1^{\,2}+b_1^{\,2}c_1^{\,2}+c_1^{\,2}a_1^{\,2}}{a_1^{\,2}b_1^{\,2}c_1^{\,2}}\right\}\right]a_1\delta a_1=0.$$

So that any internal equipotential surface is an hyperboloid of one sheet of which the square of the imaginary axis is numerically the least, or an hyperboloid of two sheets of which the square of the real axis is numerically the least. The equations of the external equipotential surfaces involve elliptic functions.

XVII.

RESEARCHES ON THE COMPLEX INORGANIC ACIDS.

By Wolcott Gibbs, M. D.,

Rumford Professor in Harvard University.

(Continued from Vol. XVII. p. 90.)

Presented May 9th, 1883.

The compounds which I have hitherto described may be embraced under the general formula

$$m\,\mathrm{R\,O_3 \,.\, 2\,R'_2O_5 \,.\,} p\,\mathrm{R''_2O}.$$

in which m may represent any even number from 10 to 48 inclusive, p the number of molecules of base (old style), R an atom of tungsten or molybdenum, and R′ one of phosphorus or arsenic. I shall now proceed to show that these results may be generalized in a variety of different ways, and, further, that there are other typical formulas, perhaps less general than that above given, but still embracing many interesting and instructive special cases.

HYPOPHOSPHO-MOLYBDATES.

Hypophospho-molybdate of Ammonium. — When solutions of 14 : 6 acid ammonic molybdate and sodic hypophosphite are mixed, no precipitate is formed, but the liquid takes a fine blue color from the partial reduction of molybdic teroxide to Mo_2O_5. On addition of chlorhydric acid and stirring for a short time, a large quantity of a crystalline salt separates. This is to be filtered off, well drained by the filter-pump, and washed with cold water, in which it is not very soluble. When perfectly pure and free from Mo_2O_5 the salt presents colorless prismatic crystals, which are readily soluble in hot water. The solution, at first pale blue, speedily assumes a deeper tint; with cold water a colorless strongly acid solution may be obtained, and with such the reactions here given were obtained. Baric chloride gives no precipitate alone, but after adding ammonia a colorless salt is thrown down, which is at first flocky, but which soon becomes fine-grained granular-crystalline. Strontic and calcic chlorides behave in a similar manner, but the calcic precipitate does not form so rapidly. Manganous sulphate gives no precipitate alone, but after adding ammonia a white flocky salt is formed, which becomes yellowish on standing. Cupric sulphate behaves in the same manner; the precipitate after the addition of ammonia is green and flocky. The mixture with solution of copper is not reduced on boiling, either alone or after addition of chlorhydric acid. The solution of the hypophospho-molybdate gives a canary-yellow precipitate with mercurous nitrate, and a nearly white precipitate with argentic nitrate, which soon becomes gray and finally black. Thallous nitrate gives a white flocky precipitate. When the dry salt is heated, it becomes at first black and fumes slightly, but on further heating it melts to a dark blue mass which gives off a little molybdic teroxide on heating to redness. The fused mass dissolves readily in hot water, forming a deep blue solution which has an acid reaction, and gives with magnesia-mixture the characteristic ammonio-magnesic phosphate. The effect of heat is represented by the equation

$$8\,MoO_3 \,.\, 2\,\{H_2 \,.\, PO \,.\, OH\}\; 2 \,.\, (NH_4)_2\,O + 2\,H_2O = \\ 8\,MoO_3 + P_2O_5 + 3\,H_2 + 2\,(NH_4)_2\,O + H_2O.$$

In the analyses the loss by ignition corresponds to 2 $(NH_4)_2O$ + H_2O + 3 H_2, and the residual mass to 8 MoO_3 + P_2O_5, when the ignition is made with sodic tungstate. In this salt, —

1.3172 gr. lost on ignition with WO_4Na_2 0.1329 gr. = 10.09 % H_2O, $(NH_4)_2O$, and H.
1.0764 gr. lost on ignition with WO_4Na_2 0.1086 gr. = 10.09 % H_2O, $(NH_4)O$, and H.
1.2369 gr. gave 0.1836 gr. NH_4Cl = 7.21 % $(NH_4)_2O$.
1.2850 gr. " 0.0918 gr. $(NH_4)_2O$ by titrition = 7.15 % "
2.4322 gr. " 0.3860 gr. $P_2O_7Mg_2$ = 9.42 % PO_2H_3.
1.6217 gr. " 0.2578 gr. " = 9.30 % PO_2H_3.

The analyses lead to the formula

$$8\,MoO_3 \,.\, 2\,\{H_2 \,.\, PO \,.\, OH\}\; 2\,(NH_4)_2\,O + 2\,aq,$$

which requires: —

		Calc'd.	Mean.	Found.	
8 MoO_3	1152	80.89	80.97	—	—
2 PO_2H_3	132	9.27	9.36	9.42	9.30
2$(NH_4)_2O$	104	7.31	7.18	7.21	7.15
2 H_2O	36	2.53	2.49	2.47	2.52
	1424	100.00	100.00		

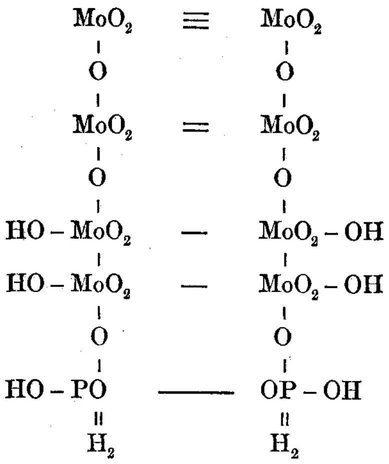
In computing the results of the analyses the loss of weight by ignition, 10.09 %, is of course taken to represent $2\,(NH_4)_2O + H_2O + 3\,H_2$, in accordance with the equation given above. In the analyses the quantity of hypophosphorous acid was determined by dissolving the salt in a solution of sodic carbonate, and then adding bromine, which with the aid of heat readily converts the hypophosphorous into phosphoric acid. The quantity of the former could not be determined by means of potassic hypermanganate in an acid solution. Bromine does not act sensibly upon acid solutions, and even an excess of nitric acid effects an imperfect oxidation. These facts, taken in connection with the relations of the salt to solutions of copper and silver, seem to show that the stability of hypophosphorous acid is increased by its combination with molybdic teroxide. The salt has, as stated, a strong acid reaction, and the limit of the basicity of this class of compounds still remains to be determined. The formula may also be written: —

$$8\,MoO_3 \,.\, 2\,\{H_2 \,.\, PO \,.\, (NH_4O)_2\}\; 2\,H_2O + 2\,aq.$$

The constitution of hypophosphorous acid was first established by Würtz. More recent investigations in organic chemistry have shown that it is to be regarded as dihydryl-phosphinic acid, and that it forms the initial term and type of an extensive series of organic acids, in which the two atoms of hydrogen attached to the phosphorus are replaced by methyl, phenyl, &c., and in which also arsenic may replace phosphorus. I do not propose at present to proceed further in this particular line of research, but will content myself with the statement that a solution of dimethyl-arsinic (kakodylic) acid gives immediately in one of 14 : 6 acid ammonic molybdate a beautiful colorless crystalline precipitate. It can hardly be doubted that this is a dimethyl-arsino-molybdate belonging to the general type represented by the formula

$$m\,MoO_3 \,.\, 2\,\{(CH_3)_2 \,.\, AsO \,.\, (OH)\}\; n\,(NH_4)_2O.$$

The structural formula of the hypophospho-molybdate above described, or rather of the corresponding acid, may be written, in accordance with the general principles already assumed, as follows: —



$$\begin{array}{rcl}
\mathrm{MoO_2} & \equiv & \mathrm{MoO_2} \\
| & & | \\
\mathrm{O} & & \mathrm{O} \\
| & & | \\
\mathrm{MoO_2} & = & \mathrm{MoO_2} \\
| & & | \\
\mathrm{O} & & \mathrm{O} \\
| & & | \\
\mathrm{HO-MoO_2} & - & \mathrm{MoO_2-OH} \\
| & & | \\
\mathrm{HO-MoO_2} & - & \mathrm{MoO_2-OH} \\
| & & | \\
\mathrm{O} & & \mathrm{O} \\
| & & | \\
\mathrm{HO-PO} & \text{———} & \mathrm{OP-OH} \\
\| & & \| \\
\mathrm{H_2} & & \mathrm{H_2}
\end{array}$$

In this formula the acid is supposed to correspond to the ammonium salt described.

HYPOPHOSPHO-TUNGSTATES.

The salts of this series are not very well defined as regards their physical properties, and it is difficult to obtain any single one in a state of perfect purity. They are most readily prepared by boiling acid tungstates with a solution of hypophosphorous acid, and appear to be in general very soluble in water, yielding sometimes thick syrupy liquids, and sometimes gelatinous masses more or less colored by the partial reduction of tungstic teroxide.

Potassic Salt. — When a strong solution of hypophosphorous acid is mixed with one of 12 : 5 acid sodic tungstate, the liquid becomes turbid and yellowish, and after a short time gelatinizes to a pale yellow mass. This is to be dissolved in boiling water, and a solution of potassic bromide added, which after a short time gives a white crystalline precipitate, to be drained upon the filter-pump, redissolved in hot water, again crystallized, drained, washed with cold water, and dried on woollen paper. As thus prepared, the salt presented small colorless granular crystals, soluble in hot water to a somewhat turbid strongly acid liquid, which effervesced with alkaline carbonates. The solution gave no precipitate with cupric sulphate, and no copper was reduced on boiling either with or without chlorhydric acid. Argentic nitrate gave a turbid white solution; on boiling, silver was reduced. Mercurous nitrate gave a white flocky precipitate, which on boiling became yellow, and finally dirty greenish yellow, without reduction of mercury. Baric chloride gave a white precipitate of indistinct feathery crystals. When heated in a porcelain crucible the salt became blue, and finally white, giving off a sharp acid smell. The residue dissolved in water, in part at least, forming a strongly acid solution. Of this salt

$$\left\{\begin{array}{l}1.2295 \text{ gr. lost on ignition } 0.0340 \text{ gr.} = 2.76\% \text{ water and hydrogen.}\\ 1.2295 \text{ gr. gave } 1.1172 \text{ gr. } WO_3 + P_2O_5 = 90.84\%\end{array}\right.$$

0.7272 gr. lost on ignition with WO_4Na_2 0.0203 gr. = 2.79%
1.5110 gr. gave 0.1921 gr. $P_2O_7Mg_2$ = 7.57% PO_2H_3

The analyses lead to the formula

$$18\ WO_3 \,.\, 6\ \{H_2 \,.\, PO \,.\, OH\}\ 4\ K_2O + 7\ aq,$$

which requires:—

		Calc'd.		Found.	
18 WO_3	4176	82.31	90.11	82.71	90.28
6 PO_2H_3	396	7.80		7.57	
4 K_2O	376	7.41		7.42	
7 H_2O	126	2.48		2.45	
	5074	100.00		100.15	

In the analysis the hypophosphorous acid was determined by oxidation with bromine in an alkaline solution and precipitation with magnesia-mixture. The formula given may be written, with equal probability,

$$18\ WO_3 \,.\, 6\ \{H_2 \,.\, PO \,.\, OK\}\ K_2O \,.\, 3\ H_2O + 7\ aq,$$

since the assignment of the fixed base is purely arbitrary; other arrangements are also possible. I am disposed to regard the salt as acid, with the formula

$$2\ (6\ WO_3 \,.\, 2\ \{H_2 \,.\, PO \,.\, OH\}\ 2\ K_2O) + 6\ WO_3 \,.\, 2\ \{H_2 \,.\, PO \,.\, OH\}\ 2\ H_2O + 5\ aq,$$

so that the type of the corresponding acid, setting aside the question of basicity, will be

$$6\ WO_3 \,.\, 2\ \{H_2 \,.\, PO \,.\, OH\}\ 2\ H_2O.$$

The structural formula of such an acid will be similar to that already given in the case of the hypophospho-molybdate described. Further investigation may, however, show that the more complex formula must be admitted. I content myself with proving that there is at least one class of hypophospho-tungstates. In computing the direct results of the analyses I have assumed that, as in the case of the corresponding molybdenum compounds, the complex $2\ \{H_2 \,.\, PO \,.\, OH\}$ is oxidized to P_2O_5 wholly at the expense of two molecules of WO_3 reduced to W_2O_5, which last is then again oxidized to $2\ WO_3$ by heating in air. This assumption appears to be justified by the changes of color observed on heating the salt. The actual loss of weight observed then corresponds to water and hydrogen only, the percentage of hydrogen being calculated from that of $P_2O_4H_6$.

When tungstic hydrate in excess is boiled with a solution of sodic hypophosphite, it dissolves very readily, giving a pale blue solution which yields on evaporation a thick syrupy liquid. This solution gives precipitates with $BaCl_2$, NH_4Cl, and KBr, and will furnish a convenient starting-point for further investigation. It does not oxidize readily in the air, even after long standing. A solution of dimethyl-arsinic acid gives with one of 12 : 5 acid sodic tungstate a beautiful colorless crystalline precipitate. I have not studied this compound, from want of proper facilities for work of the kind. It will, I think, prove to be a dimethyl-arsino-tungstate, coming under the general formula

$$m\ WO_3 \,.\, 2\ \{(CH_3)_2 \,.\, AsO \,.\, OH\}\ n\ Na_2O,$$

and we may reasonably expect an extensive series of analogous compounds, in which other radicals take the place of methyl.

PHOSPHOROSO-MOLYBDATES.

Since phosphorous acid is now to be regarded as hydryl-phosphinic acid with the formula

$$\{H \,.\, PO \,.\, (OH)_2\},$$

the existence of a class of phosphoroso-molybdates and of phosphoroso-tungstates appeared, to say the least, a probable inference from that of the hypophospho-compounds already described.

Phosphoroso-molybdate of Ammonium. — When a solution of phosphorous acid — as prepared by the reaction of phosphorous chloride with water — is added to one of 14 : 6 acid ammonic molybdate, a very pale yellow indistinctly crystalline precipitate is formed, which is insoluble in cold water. Hot water dissolves it only in a small proportion, but gives a milky emulsion, which settles very slowly. For analysis the salt was drained on a filter-pump, well washed with cold water, and finally dried on woollen paper. Of this salt, —

1.9695 gr. gave 0.0980 gr. $(NH_4)_2O$ = 4.97% by titrition.
1.1425 gr. " 0.0559 gr. " = 4.89% "
0.9301 gr. lost on ignition with WO_4Na_2 0.1225 gr. = 13.17%
1.2722 gr. gave 0.1374 gr. $P_2O_7Mg_2$ = 7.97% PO_3H_3

The analyses correspond fairly well with the formula

$$24\ MoO_3 \,.\, 4\ \{H \,.\, PO \,.\, (OH)_2\}\ 4\ (NH_4)_2O + 17\ aq,$$

which requires: —

	Calc'd.		Found.	
24 MoO_3	80.41	88.04	79.88	87.85
4 PO_3H_3	7.63		7.97	
4 $(MH_4)_2O$	4.84		4.89	4.97
17 H_2O	7.12		7.22	
	100.00			

The salt certainly contained a little phospho-molybdate, to which the faint yellow tint was probably due. It is very difficult to obtain a solution of phosphorous which is absolutely free from phosphoric acid. With respect to the formula I remark that the number of molecules of water may be purely accidental, and that there is at present no sufficient reason for rejecting the simpler expression

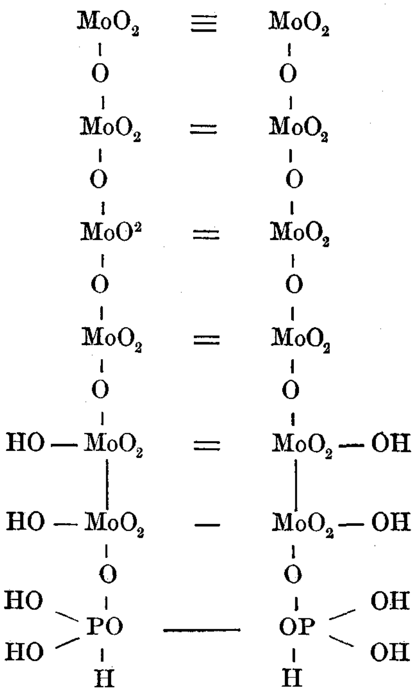
$$12\ MoO_3 \,.\, 2\ \{H \,.\, PO \,.\, (OH)_2\}\ 2\ (NH_4)_2O + x\ aq.$$

The type of the acid is then

$$12\ MoO_3 \,.\, 2\ \{H \,.\, PO \,.\, (OH)_2\}\ 2\ H_2O.$$

A solution of baric chloride boiled with the phosphoroso-molybdate decomposes it more or less completely, giving a white very fine-grained crystalline salt. Under the same circumstances argentic nitrate gives a nearly colorless flocky substance, which quickly becomes darker, and finally assumes a dull violet color. Mercurous nitrate yields a clear pale yellow flocky salt; the phosphoroso-molybdate does not reduce a solution of mercuric chloride even on boiling. Cupric sulphate dissolves the salt to a clear blue liquid. Manganous sulphate also dissolves it, forming a colorless solution. Alkaline hydrates dissolve it very readily to colorless liquids. The salt is readily decomposed by heating in a porcelain crucible, and fuses at a low red heat, giving off vapors of molybdic teroxide. The fused mass on cooling is bluish gray. It dissolves readily in water to a deep blue liquid, which has a strongly acid reaction, and gives with magnesia-mixture the reaction for phosphoric acid.

The structural formula of the acid corresponding to the ammonium salt may be written provisionally: —



If we accept the views now generally received as to the constitution of hypophosphorous and phosphorous acids, the hypophospho-molybdates, hypophospho-tungstates, and phosphoroso-molybdates furnish a much needed demonstration of the fact, that in this whole class of compounds part at least of the hydroxyl is united to phosphorus directly, and a part only to tungsten or molybdenum. This will appear at once from the formulas for the two acids, since these cannot be broken up into simpler expressions,

$$\{H_2 . PO . OH\}, \qquad \text{and} \qquad \{H . PO . (OH)_2\},$$

or from the structural formulas which I have given. I shall return to this point hereafter, and give additional proofs of the twofold mode of combination of hydroxyl.

Further investigation will almost certainly show that the homologues of hydryl-phosphinic or phosphorous acid will also form complex acids with tungstic and molybdic teroxides. Thus methyl-phosphinic acid $\{CH_3 . PO . (OH)_2\}$ should form at least one series of each of the general types: —

$$m\ MoO_3 . \{CH_3 . PO . (OH)_2\}\ n\ H_2O.$$
$$n\ WO_3 . \{CH_3 . PO . (OH)_2\}\ p\ H_2O.$$

In these cases arsenic, and perhaps antimony, may replace phosphorus. Phosphoroso-tungstates may be formed by the action of phosphorous acid upon acid tungstates. The only salt obtained at present appears to have the formula

$$12\ WO_3 . 2\ \{H . PO . (OH)_2\}\ 2\ K_2O + 12\ aq.$$

I propose to return to this special point when describing the related groups of arsenoso-tungstates and antimonoso-tungstates and the corresponding molybdates. In the analysis of the phosphoroso-molybdate of ammonium the phosphorous acid was determined by dissolving the salt in an excess of a solution of sodic carbonate, oxidizing with bromine, and precipitating with magnesia-mixture.

VANADIO-MOLYBDATES.

The general analogy between vanadic, arsenic, and phosphoric pentoxides suggested to me the possibility of forming series of vanadio-molybdates and vanadio-tungstates, belonging to types of a character similar to those of the phospho-molybdates and phospho-tungstates already described. I shall now show that such compounds may readily be formed by processes identical in principle with those which yield compounds of phosphoric and arsenic oxides with molybdic teroxide.

Vanadio-molybdates are formed when vanadic pentoxide V_2O_5 is digested with solutions of alkaline molybdates, more especially with the acid salts of potassium, sodium, or ammonium. The solution quickly becomes yellow, then, on heating, orange, and finally passes in many cases to deep orange-red. The vanadic oxide or acid employed must be perfectly free from vanadic dioxide, as this is also readily dissolved. The resulting compound then belongs to the class of triple complex acids, and contains both oxides of vanadium united to molybdic oxide. I shall return to these compounds in due time, and meanwhile shall refer to them under the name of vanadico-vanadio-molybdates. The presence even of a small quantity of vanadic dioxide may usually be detected by a peculiar greenish shade of color, easily recognized when once seen. This tint disappears when the solution is heated for a short time with bromine water or nitric acid, which readily oxidize the lower oxides of vanadium.

Vanadio-molybdates are also formed when solutions of alkaline vanadates and molybdates are heated together, and more readily when an excess of acid is present. The mixed solution then assumes at once a deep orange-red color.

The same salts are also formed when molybdic oxide, MoO_3, is boiled with a solution of an alkaline vanadate or meta-vanadate. Ammonic meta-vanadate, VO_3NH_4, may now be had in commerce in a state of very considerable purity, and has served as the starting point for much of my work. A solution of this salt readily dissolves molybdic oxide, forming one or more vanadio-molybdates, only in this case there is a tendency to a kind of supersaturation, a large excess of molybdic oxide being dissolved and separating from the liquid on cooling.

Finally, vanadio-molybdates may be formed by the decomposition of phospho-vanadio-molybdates, a class of triple compounds also to be described.

The vanadio-molybdates of the alkaline metals are in general readily soluble in water. They are highly crystalline, have a yellow or greenish yellow, sometimes orange-yellow or orange-red color, and give in many cases crystalline precipitates with salts of the alkaline earths, of silver, and of thallium. They are not decomposed by boiling with excess of acid, and are usually very stable, except in the presence of reducing agents.

Analytical Methods. — The quantitative separation of molybdenum from vanadium presented a new problem in analytical chemistry, the solution of which cost much time and labor. It may be effected in two different ways. When the vanadium is wholly or partially in the form of vanadic dioxide, VO_2, it is to be oxidized by heating the concentrated solution with nitric acid. An alkaline carbonate is then to be added until the solution is nearly neutral, when the vanadic and molybdic oxides may be precipitated together by means of mercurous nitrate and mercuric oxide, precisely as in the estimation of tungstic oxide already described. The precipitate of mercurous vanadate and molybdate and mercuric oxide is to be filtered upon a paper filter. After drying, the filter and contents may be heated together in a platinum crucible, with free access of air. When the process is carefully conducted, the filter may be completely incinerated with great ease, and without loss of molybdic oxide from volatilization. A weighed quantity of fused and pulverized neutral sodic tungstate is then to be added, when the crucible may be heated to redness, and the mercurous and mercuric oxides completely expelled. A second heating and weighing are always advisable. In this manner the sum of the weights of molybdic and vanadic oxides is obtained. To determine the quantity of vanadic oxide alone, the same process is to be repeated; only after burning off the filter the mass is to be carefully heated with a free supply of air to act mechanically until the whole of the molybdic oxide is volatilized and vanadic oxide remains as an orange-brown liquid, and, after cooling, as a crystalline mass. The complete expulsion of the molybdic oxide requires long heating, at a full red heat. The vanadic oxide is not volatile, but it has the inconvenient habit of creeping up the sides and over the edge of the crucible, — a habit for which there appears to be no remedy. The weight of the molybdic oxide may then be determined by difference. This method gives good results, and in some cases may be used with advantage.

Another method is the following, which applies directly to the vanadio-molybdates of the alkaline metals, and to those of the alkaline earths, after the separation of the base. Ammonia is to be added in excess to the solution, which is then to be boiled for a few minutes, so as to convert the salt into a mixture of an alkaline vanadate and molybdate. A saturated solution of ammonic chloride is then added in very large excess, after which the liquid must be concentrated by continued boiling until reduced to a relatively small volume. The solution must then be allowed to stand for twenty-four hours, when a greater or less deposit of ammonic meta-vanadate will have formed in colorless crystals.* These crystals are to be brought upon an asbestos filter, and washed with a cold saturated and pure solution of ammonic chloride. The vanadic pentoxide may then be found by carefully igniting the salt with free access of air. It is, however, better to dissolve the salt upon the filter with boiling water, reduce the solution by means of a current of sulphydric acid gas after adding a little sulphuric acid, filter, and titrate with potassic hypermanganate. The clear blue solution contains vanadic dioxide only. The end reaction is tolerably sharp in dilute solutions — say 0.25 gramme — of VO_2 in 250 c. c. of water. The reason for adopting the method of titrition is, that the ignition of ammonic meta-vanadate, even when conducted with great care, usually yields a mixture of vanadic pentoxide and dioxide, which it is difficult to oxidize completely. The precipitation of ammonic meta-vanadate by ammonic chloride is, as is well known, not absolutely complete, but the results of the analyses are on the whole fairly good.

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* The best commercial chloride of ammonium always contains iron not precipitable by ammonia. If bromine water be added first to the boiling solution, ammonia in small quantity separates the iron completely.

It is sometimes more advisable to employ a combination of the two methods described. After precipitating the two oxides by means of mercurous nitrate and mercuric oxide, the greater part of the molybdic oxide may be expelled by heat, after which the mixture of oxides, which now consists chiefly of vanadic pentoxide, may be dissolved in ammonia and treated with ammonic chloride in the manner above described. The quantity of molybdic oxide is most easily estimated by difference, the sum of the weights of the two oxides being determined by the method given above. It is not possible to reduce the vanadic pentoxide in the vanadio-molybdates to vanadic dioxide by means of sulphydric acid gas, by sulphurous oxide, or by any other reagent which I have tried, without at the same time reducing a portion of the molybdic teroxide to the blue oxide Mo_2O_5. This difficulty may however be overcome by first adding phosphoric acid to the solution in quantity about equal to the weight of the salt analyzed. After the addition of a little sulphuric acid the reduction of the vanadic pentoxide may be effected either by boiling with a solution of sulphurous oxide, or by passing sulphydric acid gas for some time through the hot solution of the salt.

In separating vanadic from molybdic oxide by means of ammonic chloride it is necessary to keep the solution always slightly alkaline by the occasional addition of a little ammonia, since, as soon as the liquid becomes acid by the dissociation of the ammonium salts present, a vanadio-molybdate is again formed in greater or less quantity. To resolve a vanadio-molybdate into a mixture of vanadate and molybdate, it is necessary to employ an excess of free ammonia, and also to heat the solution. Actual boiling is most advantageous.

Another method of estimating vanadic oxide in the presence of molybdic teroxide consists in boiling the compound with strong chlorhydric acid, passing the chlorine set free into a solution of potassic iodide, and then determining the free iodine volumetrically by sodic hyposulphite and starch. I have not actually employed this method, however, though it gives excellent results in the analysis of the vanadio-tungstates.

It will be convenient to speak in this place of the best method of determining vanadium in alkaline vanadates without special reference to its separation from other elements. I find that this estimation may be effected with great accuracy by first oxidizing any lower oxide which may be present by means of nitric acid to vanadic pentoxide, and then precipitating the faintly acid solution by mercurous nitrate and an excess of mercuric oxide at a boiling heat. Precipitation by mercurous nitrate alone was long since suggested by Berzelius, but the addition of mercuric oxide to render and to keep the solution neutral makes precisely the difference between a very accurate and an only tolerably good result. The precipitate may be collected upon a paper filter, and after washing with hot water ignited with free access of air. On cooling, a fine orange-brown crystalline mass of vanadic pentoxide remains. The filtrate from the precipitated oxides contains no appreciable trace of vanadium. The great facility with which a solution of vanadic pentoxide containing free chlorhydric acid is reduced by ferrous salts, suggested the possibility of determining vanadium by titrition with ferrous sulphate, a solution of potassic ferricyanide being employed to determine the point of complete reduction.

A special study of this process was made in my laboratory by my assistant, Mr. Charles A. French, to whom the following details are exclusively due. The solution containing vanadic pentoxide is to be concentrated, and chlorhydric acid solution containing about one tenth of its weight of pure acid added in large excess. After nearly saturating with a solution of ferrous or ammonio-ferrous sulphate of known titre, the solution is to be heated nearly to boiling, and the titrition then completed with the ferrous salt, the end reaction being determined by trial drops upon a porcelain plate with a very dilute solution of potassic ferricyanide. Of this solution two drops of the ordinary laboratory reagent in a test-tube full of water give an appropriate strength. The process may be varied by adding the ferrous solution in excess, then titrating back by means of potassic dichromate of known titre, and finally adding the ferrous salt until the end reaction with ferricyanide is obtained. The ferrous solution may contain with advantage 0.005 gr. of iron in one cubic centimeter. A sample of potassic divanadate containing no other impurity than a little potassic nitrate gave, by the gravimetric process above described, 65.12% V_2O_5. In three successive titritions with ammonio-ferrous sulphate Mr. French found 65.16, 65.27, and 64.95%.

As ammonic meta-vanadate is now largely used in the manufacture of aniline black, and has become an article of commerce, the method of titrition described above may perhaps find useful application in technical laboratories, as the end reaction in titrating with hypermanganate is not very sharp. I have in my work employed it in several cases as a check upon other methods.

In the analyses of vanadio-molybdates it is best to determine the alkalies by difference, as in the cases of the phospho-molybdates and phospho-tungstates. As in these cases also ammonia and water are best determined together by ignition with a weighed portion of neutral sodic tungstate, WO_4Na_2, a method suggested by Dr. F. A. Gooch for the whole class of phospho-tungstates and phospho-molybdates of ammonium; only in the case of the vanadio-molybdates and other salts containing both molybdenum and vanadium, it is necessary to be especially careful in igniting with the tungstate, because molybdic teroxide is sometimes given off before the complete fusion of the tungstate with the salt.

6 : 1 *Series.* — A solution of ammonic meta-vanadate, VO_3NH_4, readily dissolves molybdic teroxide on boiling, forming a deep orange-yellow solution. The liquid on standing deposits a very beautiful lemon-yellow salt, in sharp octahedral crystals, which are soluble in a rather large excess of cold water without sensible decomposition. The solution, on spontaneous evaporation, yields the salt without change. Of this salt, —

1.1349 gr. lost on ignition with WO_4Na_2 0.1806 gr. = 15.91%
1.3220 gr. " " " " 0.2128 gr. = 16.09%
1.5022 gr. " " " " 0.2412 gr. = 16.05%
1.2477 gr. gave 0.2201 gr. NH_4Cl = 8.57% $(NH_4)_2O$
1.3822 gr. " 0.2439 gr. " = 8.57% "
1.2847 gr. " 0.1893 gr. V_2O_5 by $KMnO_4$ = 14.73%

The analyses lead to the formula

$$6\ MoO_3 \cdot V_2O_5 \cdot 2\ (NH_4)_2O + 5\ aq,$$

which requires: —

		Calc'd.	Found.		
6 MoO_3	864	69.62			
V_2O_5	183	14.74	14.73		
2 $(NH_4)_2O$	104	8.39	8.57	8.57	
5 H_2O	90	7.25	7.34	7.52	7.48
	1241	100.00			

The reactions of a solution of this salt in cold water are as follows. No precipitate with salts of copper, zinc, manganese, and cadmium. Argentic nitrate gives a flocky yellow precipitate, with a tinge of buff. Mercurous nitrate gives a bright yellow precipitate. Thallous nitrate gives a very pale yellow flocky precipitate, which does not become crystalline on standing. Baric chloride gives no precipitate at first, but after a short time very beautiful sharp octahedral crystals: after longer standing small pale yellow very distinct prismatic crystals also appear in the solution. Strontic chloride gives, after some days, very well defined pale yellow prismatic crystals. The solution of the vanadio-molybdate gives a rather dull yellow flocky precipitate with hydro-chloride of brucin, and a bright yellow one with hydro-chloride of strychnin. No precipitate is formed at first with potassic bromide, but after some days beautiful very well defined granular crystals are deposited in quantity.

The solution of the salt has a strongly acid reaction. The mercurous salt is decomposed by dilute chlorhydric acid, with formation of mercurous chloride and a yellow acid solution, doubtless of the acid of this series. The acid was decomposed by spontaneous evaporation, and did not yield crystals.

It appears unnecessary to give a structural formula for the salt described, since we may regard V_2O_5 as simply replacing P_2O_5, and with the same function as this last, so that the structural formulas already given for the phospho-tungstates will apply to the present case also.

Eight Atom Series. — When acid ammonic molybdate is dissolved, and vanadic pentoxide is added in small quantities at a time, the boiling solution quickly becomes yellow, and then orange. If the vanadic oxide is not perfectly free from dioxide, VO_2, a little bromine water should be employed to complete the oxidation. If a solution of baric chloride be mixed with the rather dilute and warm solution, no precipitate is formed at first, but after a few seconds an abundance of beautiful yellow well-defined crystals appears. These crystals are very sharp octahedra, and strongly resemble those of one of the ammonium salts of the six-molecule series. After a time granular yellow crystals make their appearance also in large quantity. The habitus of these crystals is so different from that of the first named that the two can readily be separated when mixed. A very approximate separation can also be effected by pouring off the liquid the moment that the granular crystals begin to appear. The yellow octahedral crystals are soluble in hot water, containing a little chlorhydric acid, and may be recrystallized. When heated, the salt swells up very much, and turns black, looking like coke. Of this salt, —

1.0070 gr. lost on ignition with WO_4Na_2 0.1310 gr. = 13.00%
0.9716 gr. " " " " 0.1280 gr. = 13.17%
1.2449 gr. " " " " 0.1637 gr. = 13.16%
0.9682 gr. gave 0.6534 gr. $MoO_3 + V_2O_5$ = 67.48%
1.0162 gr. " 0.3029 gr. SO_4Ba = 19.56%
1.0343 gr. " 0.3072 gr. " = 19.50%
1.0190 gr. " 0.3023 gr. " = 19.48%
1.0937 gr. " 0.0998 gr. V_2O_5 = 9.12%
1.4395 gr. " 0.1356 gr. " = 9.37%

These analyses lead to the formula

$$16\ MoO_3 \,.\, 2\ V_2O_5 \,.\, 5\ BaO + 29\ aq,$$

or,

$$8\ MoO_3 \,.\, V_2O_5 \,.\, 3\ BaO + 8\ MoO_3 \,.\, V_2O_5 \,.\, 2\ BaO \,.\, H_2O + 28\ aq,$$

which requires: —

		Calc'd.		Found.	
16 MoO_3	2304	58.25		58.34	
2 V_2O_5	364	9.21		9.12	9.37
5 BaO	765	19.35	19.48		19.56
29 H_2O	522	13.19	12.96	13.00	13.16
	3955	100.00			

The salt is therefore to be regarded as the acid salt of the eight-atom series, and belongs to a type of which several examples have been given among the phospho-tungstates and phospho-molybdates. It may also be considered as an acid sixteen-atom salt, upon the view which I have suggested in another place as at least possibly correct. The 16 : 2 barium salt is also formed when baric chloride is added to a solution of the 6 : 1 vanadio-molybdate of ammonium already described. The last-named salt is therefore formed when vanadic pentoxide is dissolved in acid ammonic molybdate, as well as when molybdic oxide is dissolved in ammonic meta-vanadate. In the double decomposition with baric chloride at least three molecules of the 6 : 1 ammonium salt must take part. The barium salt is nearly insoluble in cold water, but is soluble in much hot water, with partial decomposition and deposition of baric molybdate. The solution in cold water reddens litmus strongly: it gives with argentic nitrate a pale, and with mercurous nitrate a bright yellow flocky precipitate.

The first determination of vanadic pentoxide in this salt was made by heat alone, the mixture of molybdic and vanadic oxides being ignited until a constant weight was obtained. In the second analysis the determination was made by titrition with ferrous sulphate after adding chlorhydric acid to the solution.

Eighteen Atom Series. — A boiling solution of ammonic metavanadate readily dissolves molybdic teroxide, MoO_3, forming a deep yellow or orange-yellow solution. When the oxide is added as long as it is readily dissolved, an olive-green liquid is obtained, from which after twenty-four hours hard tabular crystals of a pale greenish color are deposited. These crystals are decomposed by boiling water, beautiful yellow needles very slightly soluble in water, being formed, together with a greenish yellow solution which soon becomes turbid. The salt could not be purified by recrystallization, and was therefore washed with a little cold water and dried on woollen paper. Of this salt, —

0.8067 gr. ignited with WO_4Na_2 lost 0.1586 gr. = 19.66%
0.8538 gr. gave 0.2140 gr. NH_4Cl = 12.18% $(NH_4)_2O$
1.0243 gr. " 0.2526 gr. " = 11.99% "
0.7945 gr. " 0.0407 gr. V_2O_5 = 5.12%

These analyses correspond to the formula

$$18\ MoO_3 \,.\, V_2O_5 \,.\, 8\ (NH_4)_2O + 15\ aq.$$

		Calc'd.	Found.	
18 MoO_3	2592	74.89	75.22	
V_2O_5	183	5.29	5.12	
8 $(NH_4)_2O$	416	12.02	11.99	12.18
15 H_2O	270	7.80	7.58	
	3461	100.00		

A more extended investigation will, undoubtedly, show that the vanadio-molybdates are, to say the least, numerous. The salts which I have described are sufficient to establish a parallelism between them and the phospho-molybdates, which is the more interesting because the chemical relations of vanadium are nearer to antimony than to phosphorus and arsenic. I shall return to this point, however, in describing and discussing the class of antimonio-tungstates and antimonio-molybdates.

VANADIO-TUNGSTATES.

Vanadio-tungstates are very readily formed under conditions precisely the same as those which determine the formation of vanadio-molybdates, and which it is unnecessary to recapitulate. As a class, they have a yellow, orange, or orange-red color. They are, so far as examined, readily soluble in water, are crystalline and extremely stable in composition, in the sense at least that it is often difficult to separate the combined vanadic and tungstic oxides, though in many cases complex salts easily break up into compounds of simpler type.

Analytical Methods. — When alkaline vanadates and tungstates are simply mixed together under conditions which do not result in the formation of vanadio-tungstates, it is possible to effect the separation of the vanadic and tungstic oxides by means of a solution of ammonic chloride, which, as is well known, precipitates ammonic meta-vanadate in colorless crystals nearly insoluble in a saturated solution of ammonic chloride. This method cannot be applied directly to the separation of the two oxides when combined, as in the vanadio-tungstates, but the difficulty can be overcome by either of the following methods. An excess of ammonia is to be added to the solution, which is then to be digested, or, if necessary, boiled until the liquid becomes colorless. By this process, which, however, does not always perfectly succeed, the vanadio-tungstate is resolved into a mixture of ammonic tungstate and meta-vanadate. In place of ammonia, sodic or potassic hydrate in excess may be employed, and frequently with advantage. After the resolution of the vanadio-tungstate, as indicated by the color of the liquid, ammonic meta-vanadate may be precipitated by boiling with an excess of ammonic chloride. From the cold solution completely saturated with ammonic chloride the meta-vanadate my be separated by filtration, and the vanadic pentoxide estimated in the manner already pointed out. A variation of this process, which may often be employed with advantage, consists in fusing the vanadio-tungstate with an excess of potassic or sodic carbonate in a platinum crucible. The fused mass must be boiled with a strong solution of ammonic chloride, a drop or two of ammonia being added from time to time to keep the solution distinctly alkaline. The ammonic meta-vanadate is to be separated and treated as above. In applying these methods it is important in each case to be sure that the vanadium is exclusively in the form of pentoxide. It is therefore always advisable to add a little bromine water to the solution of the vanadio-tungstate before adding the excess of ammonia. In fusing with alkaline carbonates a little potassic or sodic nitrate may be added to the mixture in the crucible. In this manner we may avoid the error which would result from the presence of vanadic dioxide in the small quantity which often exists in consequence of the reducing agency of dust or traces of organic matter.

After a great number of trials, the methods given above are the only ones by which I have found it possible to effect even an approximate separation of vanadic and tungstic oxides in combination.

In place of the actual separation of the oxides, it is much more convenient, and I believe also in general much more accurate, to employ the following process, which permits us to estimate vanadium quantitatively in presence of tungstic, as well as of various other oxides. This process depends upon the fact that vanadic pentoxide, either free or in combination, when boiled with strong chlorhydric acid, evolves chlorine, which may be collected in a solution of potassic iodide. The iodine set free may then be estimated with great accuracy by means of sodic hyposulphite after adding a solution of starch.

The fact that vanadic pentoxide evolves chlorine on heating with chlorhydric acid was, so far as I have been able to find, first remarked by Mohr, who in his well-known work on volumetric analysis suggested as possible the method of determining vanadium which I have employed, without, however, testing it in any single case.

It is possible, in some cases at least, to determine vanadic pentoxide in the presence of tungstic oxide by titrition with hypermanganate. To the solution of the substance containing both metals, phosphoric and sulphuric acids are to be added, and the vanadic pentoxide is then to be reduced to dioxide by means of sulphydric acid gas passed into the boiling solution until complete reduction is obtained. No appreciable quantity of tungstic oxide is reduced under these circumstances. The titrition with hypermanganate may then usually, though not always, be executed, and gives a fairly good result.

Finally, the method of titrition by ferrous salts may often be used with success. The details have already been given, and do not need to be repeated.

5 : 1 *Vanadio-tungstate of Ammonium.* — When 12 : 5 ammonic tungstate is boiled with a solution of ammonic meta-vanadate an orange solution is obtained, which on evaporation deposits orange-yellow crusts of indistinct crystals. The color of this salt is somewhat dull; it is not very soluble in cold, but soluble in boiling water, and may be recrystallized without sensible decomposition. The salt becomes greenish upon the surface when dried upon woollen paper, from a slight superficial reduction of the vanadic pentoxide. Of this salt, —

1.0558 gr. gave 0.1222 gr. $(NH_4)_2O$ by titrition = 11.57%
1.1873 gr. lost on ignition 0.2922 gr. = 24.61% H_2O and NH_3
1.0558 gr. gave by titrition with $KMnO_4$ 11.09% V_2O_5

The analyses lead to the formula

$$5\ WO_3 \cdot V_2O_5 \cdot 4\ (NH_4)_2O + 13\ aq,$$

or

$$5\ WO_3 \cdot V_2O_5 \cdot 4\ (NH_4)_2O \cdot 2\ H_2O + 11\ aq,$$

if we regard the acid provisionally as 6-basic, which requires:—

		Calc'd.	Found.
5 WO_3	1160	64.99	—
V_2O_5	183	10.26	11.09
4 $(NH_4)_2O$	208	11.65	11.57
13 H_2O	234	13.10	13.04
	1785	100.00	

The percentage of vanadic oxide found is too high, but there can be no reasonable doubt as to the formula. I obtained the salt but once, and then in small quantity. The solution gives a dull yellow flocky precipitate with argentic and mercurous nitrates, and after a time a yellow crystalline precipitate with excess of potassic bromide. The ammonium salt is interesting as being probably the first term in a series. It corresponds to the phospho-molybdate

$$5\ MoO_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O \cdot 3\ H_2O + 4\ Aq.$$

The following may serve as starting points for further investigation. When normal baric tungstate, WO_4Ba, is boiled for a long time with a solution of ammonic meta-vanadate, it is very slowly dissolved to an orange-yellow solution, which on cooling gives very beautiful square tabular deep red crystals mixed with excess of baric tungstate. 12 : 5 baric tungstate dissolves more readily in the meta-vanadate, and gives a bright orange-yellow solution, which on evaporation yields fine prismatic crystals. From the above it appears probable that the tungstates of the heavy metals, both neutral and acid, will yield vanadio-tungstates by boiling with alkaline vanadates, and possibly in this manner various new series of salts may be formed. The costliness of the material for this work has prevented a more thorough study on my own part.

10 : 1 *Vanadio-tungstic Acid.* — A solution of ammonic meta-vanadate dissolves tungstic oxide readily on boiling, giving a deep orange-

yellow solution. After long boiling with an excess of the oxide, the clear deep orange filtrate gives, with a solution of chloride of trimethyl-ammonium, on standing some hours, two distinct kinds of crystals, which are respectively yellow and deep orange-red. There are therefore, apparently at least, two different salts formed in the solution of the tungstic oxide. The solution of the ammonium salt gave with baric chloride, after some hours, sharp octahedral crystals of a yellow salt but slightly soluble even in hot water. In a second experiment, baric chloride gave at once a yellow fine-grained crystalline insoluble precipitate; but the precipitation was not complete. On boiling the mixture of oxides obtained by igniting ammonic meta-vanadate in air with 12 : 5 sodic tungstate, I obtained a greenish-orange solution. This was oxidized by boiling with nitric acid, when it became orange. On standing, the acid solution deposited a relatively large quantity of a sulphur-yellow crystalline body, which was but very slightly soluble in cold water, and required a large quantity of hot water for complete solution. This substance was drained upon the filter-pump, washed with cold water, and dried upon woollen paper. Of this preparation, —

$$\left\{\begin{array}{l}0.8331 \text{ gr. lost on ignition } 0.1188 \text{ gr.} = 13.42\% \\ 0.8331 \text{ gr. gave } 0.7192 \text{ gr. } WO_3 + V_2O_5 = 86.03\%\end{array}\right.$$

0.9786 gr. " 0.8411 gr. " = 85.95%

1.0846 gr. " 0.0718 gr. V_2O_5 = 6.62%

The analyses correspond with the formula

$$10\ WO_3 \cdot V_2O_5 \cdot 6\ H_2O + 16\ aq,$$

which requires: —

		Calc'd.		Found.	
10 WO_3	2320	80.53	86.88	80.30	86.92
V_2O_5	183	6.35		6.62	
22 H_2O	378	13.12		13.08	
	2899	100.00			

I did not succeed in obtaining salts corresponding to the 10 : 1 acid above described by saturating the acid with alkaline bases, as mixtures of the acid with alkaline vanadates and tungstates were formed until the point of complete saturation was reached.

18 : 1 *Vanadio-tungstic Acid.* — The orange-yellow mother liquor from which the 12 : 1 acid separated gave on evaporation beautiful crystalline needles of a second acid, the formula of which is

$$18\ WO_3 \cdot V_2O_5 \cdot 6\ H_2O + 30\ aq.$$

Of this acid, —

1.0343 gr. lost on ignition 0.1342 gr. = 12.97% water.
1.0343 gr. gave 0.0363 gr. V_2O_5 = 3.51%
1.2540 gr. lost on ignition 0.1617 gr. = 12.90%

The formula requires: —

		Calc'd.		Found.		
18 WO_3	4176	83.40	87.05		83.55	87.06
V_2O_5	183	3.65			3.51	
36 H_2O	648	12.95		12.90	12.97	
	5007					

The sum of the two oxides is determined by difference, which is the most accurate method whenever applicable. In this, as in all the other vanadio-tungstic compounds analyzed, the vanadic pentoxide was determined by boiling with chlorhydric acid in the manner already described. The crystals of the 18 : 1 acid are readily soluble in water, and may be recrystallized without decomposition.

The compounds which I have described appear to establish a complete analogy between the vanadio-tungstates and phospho-tungstates already described. Rammelsberg* has described a salt which crystallizes in beautiful brown-black cubo-octahedrons, and which he obtained by saturating a commercial sodic vanadate with acetic acid and evaporating spontaneously. According to his analyses, the salt has the formula

$$(NH_4)_2O \cdot WO_3 \cdot 3\, V_2O_5 + 6 \text{ aq}.$$

I suspect that it contains VO_2 as well as V_2O_5. I did not succeed in preparing it by synthesis, employing pure VO_3NH_4 and $WO_4(NH_4)_2$. It may prove to be the type of an entirely new class of complex acids, and well deserves further investigation.

PHOSPHO-VANADIO-MOLYBDATES.

Triple acids of this class are formed when solutions of phospho-vanadates are digested with molybdic teroxide; when vanadio-molybdates and alkaline phosphates are heated together in solution, especially in the presence of an acid; and when vanadic pentoxide is heated with a solution of an alkaline phospho-molybdate.

The salts of this class are as a whole less stable than the vanadio-molybdates. They are, however, very well defined, and usually highly crystalline. In color they vary from an orange to a deep garnet, or ruby red. In general character they closely resemble the salts of the double compounds already described, and are often very beautiful.

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* Berichte der Deutschen Chem. Gesellschaft, i. 161.

Analytical Methods. — These are for the most part similar to those which I have already described. The three oxides may be precipitated together by mercurous nitrate and mercuric oxide, and then ignited with sodic tungstate in the manner described for the analysis of phospho-molybdates and arsenio-molybdates. The phosphoric oxide cannot be determined with accuracy by direct precipitation with magnesia-mixture. It is necessary first to remove the vanadic oxide. This may be done by dissolving the salt, adding ammonia in small but distinct excess, and afterward ammonic nitrate in large quantity. The solution is to be boiled for a short time, care being taken that after boiling free ammonia shall still be present. After standing in the cold for twenty-four hours the precipitated ammonic meta-vanadate may be filtered off, washed with a cold concentrated solution of ammonic nitrate, and titrated in the manner which I have described in speaking of the vanadio-molybdates. In the filtrate from the meta-vanadate phosphoric oxide may be determined by double precipitation with magnesia-mixture and final treatment with ammonic sulphide. Molybdic oxide is best determined by difference, the sum of the weights of the three oxides being known. Water, ammonia, and basic oxides may be found by the methods which I have already described in the cases of the binary compounds.

48 : 2 : 1 *Series.* — When 10 : 2 acid phospho-molybdate of ammonium, $10\,MoO_3 . 2\,P_2O_5 . 5\,(NH_4)_2O + 6$ aq., and ammonic meta-vanadate are dissolved together, there appears to be no reaction; but if a small excess of chlorhydric acid is added, and the solution is boiled, a beautiful deep orange-red crystalline precipitate is formed at once. This may be drained on a filter and washed with cold water, in which it is but slightly soluble. Hot water dissolves it rather more freely, but the salt cannot be purified by recrystallization, as it is more or less completely decomposed by solution. Ammonia water dissolves it, forming a colorless liquid, in which baric acetate produces a nearly colorless precipitate. Of this salt, —

1.3011 gr. lost on ignition with WO_4Na_2 0.1399 gr. = 10.75% $NH_3 + H_2O$
1.0425 gr. lost on ignition with WO_4Na_2 0.1124 gr. = 10.78% $NH_3 + H_2O$

1.5611 gr. gave 0.1361 gr. NH_4Cl = 4.24% $(NH_4)_2O$
1.0113 gr. " 0.0900 gr. " = 4.32% "
1.3997 gr. " with MnO_4K 0.0304 gr. V_2O_5 = 2.17%
{ 1.9173 gr. " " " 0.0463 gr. " = 2.41%
{ 1.9173 gr. " 0.1112 gr. $P_2O_7Mg_2$ = 3.71% P_2O_5

In the last two analyses the vanadic pentoxide was first separated by ammonic nitrate as VO_3NH_4; the phosphoric oxide was then determined in the filtrate.

The analyses correspond fairly well with the formula

$$48\ MoO_3 \,.\, 2\ P_2O_5 \,.\, V_2O_5 \,.\, 7\ (NH_4)_2O + 30\ aq.$$

		Calc'd.	Mean.	Found.	
48 MoO_3	6912	83.45	83.23	83.23 (diff.)	
2 P_2O_5	284	3.43	3.71	3.71	
V_2O_5	183	2.21	2.29	2.17	2.41
7 $(NH_4)_2O$	364	4.39	4.28	4.32	4.24
30 H_2O	540	6.52	6.50	6.50	6.51
	8283	100.00			

The compound may be regarded as a double salt, with the formula

$$2\{16\ MoO_3 \,.\, P_2O_5 \,.\, 2\ (NH_4)_2O \,.\, H_2O\} + \\ 16\ MoO_3 \,.\, V_2O_5 \,.\, 3\ (NH_4)_2O + 28\ aq,$$

though, of course, other arrangements of the constituents are, in the present state of our knowledge, equally probable. Thus, we may also represent the results of the analyses by the expression,

$$2\{12\ MoO_3 \,.\, P_2O_5 \,.\, 2\ (NH_4)_2 \,.\, H_2O\} + \\ 24\ MoO_3 \,.\, V_2O_5 \,.\, 3\ (NH_4)_2O + 28\ aq.$$

14:1:8 *Series.* — The beautiful yellow crystalline phospho-molybdates of ammonium, containing respectively twenty-four and twenty-two molecules of MoO_3 to one molecule of phosphoric oxide, slowly dissolve when boiled with a solution of ammonic meta-vanadate, giving a very fine deep orange-red liquid. After standing a few hours, the solution gives splendid deep ruby-red crystals in large quantity. These crystals appear to be octahedra; they dissolve readily in hot water to a deep orange-red liquid, without undergoing any apparent decomposition, and the salt crystallizes from the solution unchanged. The solution gives no precipitate at first with baric chloride, but after a time very fine garnet-red crystals are formed in small quantity, mixed with a pale orange flocky or indistinctly crystalline substance, with an orange-red supernatant liquid. Potassic bromide in large excess gives an orange crystalline, and argentic nitrate a cinnamon-colored not distinctly crystalline precipitate. Mercurous nitrate and plumbic acetate give orange precipitates. A solution of chloride of trimethylammonium, $N(CH_3)_3HCl$, gives an orange precipitate in the concentrated solution, soluble in boiling water, and crystallizing in beautiful small granular crystals, which are orange with an aurora-red tint. The crystals of the ruby-red salt became duller upon the surfaces when dried on woollen paper, but did not distinctly effloresce. Of this salt, —

1.0686 gr. lost on ignition with WO_4Na_2 0.2833 gr. = 26.51% NH_3 and H_2O
1.3051 gr. gave 0.2245 gr. NH_4Cl = 8.36% $(NH_4)_2O$
1.1020 gr. " 0.3253 gr. V_2O_5 = 29.51%
1.1113 gr. " 0.0598 gr. $P_2O_7Mg_2$ = 3.44% P_2O_5

The analyses lead to the formula,

$$14\,MoO_3 \cdot P_2O_5 \cdot 8\,V_2O_5 \cdot 8\,(NH_4)_2O + 50\,aq.$$

		Calc'd.		Found.	
14 MoO_3	2016	40.83	73.36	40.54	73.49
8 V_2O_5	1464	29.64		29.51	
P_2O_5	142	2.89		3.44	
8 $(NH_4)_2O$	416	8.42		8.36	
50 H_2O	900	18.22		18.14	
	4938	100.00			

If we assume that in this salt vanadic pentoxide stands in a relation to phosphoric oxide exactly analogous to that of molybdic teroxide, the compound will be of the same type as the phospho-molybdate already described,

$$22\,MoO_3 \cdot P_2O_5 \cdot x\,R_2O,$$

since we may write V_2O_5 as if its rational formula were $V_2O_2 \cdot O_3$.

In some preparations of this salt I observed the formation of two other salts in relatively small quantity. One of these formed pale orange-colored needles; the other, glimmering scales but slightly soluble in hot water.

PHOSPHO-VANADIO-TUNGSTATES.

These compounds bear a general resemblance to the phospho-vanadio-molybdates already described, and may be prepared by similar processes. They have usually a more or less deep orange or orange-red color, and very often exhibit a peculiar and highly characteristic aurora-red tint. They are crystalline and well defined, and many salts of the different series are very beautiful.

Analytical Methods. — In all these salts it will, as in similar cases, be found most advantageous to determine the three acid-forming oxides by means of mercurous nitrate and mercuric oxide in the manner already pointed out. The estimation of phosphoric oxide may usually be made with a fair approximation to precision by direct precipitation with magnesia-mixture in the ammoniacal solution, redissolving the ammonio-magnesic phosphate, and precipitating a second time. In some cases I have found it better first to reduce the vanadic pentoxide to vanadic dioxide by boiling with strong chlorhydric acid, evaporating to dryness, and redissolving with the addition of a little tartaric and chlorhydric acids. A perfectly satisfactory method of estimating phosphoric oxide in these compounds remains to be discovered. Vanadic pentoxide may be estimated with accuracy by the methods already pointed out for the analysis of the vanadio-tungstates; that is, by boiling with strong chlorhydric acid, collecting the chlorine evolved in a solution of potassic iodide, and determining the free iodine by titrition with sodic hyposulphite. A solution of potassic hypermanganate does not always oxidize vanadic dioxide in presence of tungstic, phosphoric, and free sulphuric acid, or only with great difficulty, so that the method is not generally applicable for the analysis of this class of compounds. Nitric acid, however, readily oxidizes the dioxide under the same circumstances.

60 : 3 : 1 *Series.* — When the white insoluble phospho-tungstates of ammonium containing twenty-two or twenty-four molecules of tungstic to one of phosphoric oxide are dissolved in ammonia water, and a solution of ammonic meta-vanadate is added, no precipitate is formed; but if a small excess of chlorhydric acid is present in the boiling liquid, a fine lemon-yellow crystalline precipitate soon forms, which is to be well washed with a cold dilute solution of ammonic nitrate, as otherwise the salt passes readily through the filter, giving a milky liquid. The final washing may be made with a very dilute solution of the nitrate. After drying on woollen paper, the salt closely resembles tungstic oxide in color. It is almost insoluble in cold, and but slightly soluble in hot

water, but with a large excess of ammonic phosphate it dissolves to a yellow solution; with ammonia water it gives a colorless solution. In a solution of ammonic carbonate it dissolves with strong effervescence, indicating its distinctly acid character. The salt is not readily reduced by boiling with sulphuric and sulphurous acids, or by citric acid in the presence of chlorhydric acid, but easily by boiling with a strong solution of potassic cyanide, and, as is usual with this class of compounds, by fusion with the same salt.

Of this compound, —

2.0684 gr. lost on ignition with WO_4Na_2 0.2068 gr. = 10.00% NH_3 and H_2O
1.0971 gr. gave 0.0747 gr. NH_4Cl = 3.31% $(NH_4)_2O$
1.3424 gr. " 0.0568 gr. P_2O_7Mg = 2.71% P_2O_5
2.5488 gr. " 0.1102 gr. " = 2.77% "
1.0555 gr. " 0.0123 gr. V_2O_5 = 1.16%

The analyses correspond very closely to the formula,

$$60\ WO_3 \cdot 3\ P_2O_5 \cdot V_2O_5 \cdot 10\ (NH_4)_2O + 60\ aq,$$

which requires: —

		Calc'd.		Found.		
60 WO_3	13920	86.29	90.00	86.10 (diff.)		90.00
3 P_2O_5	426	2.64		2.71	2.77	
V_2O_5	183	1.15		1.16		
10 $(NH_4)_2O$	520	3.23	9.92	3.31		10.00
60 H_2O	1080	6.69		6.69		
	16129	100.00				

The compound is very probably a double salt, and may have the formula,

$$3\ \{16\ WO_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O\} + 12\ WO_3 \cdot V_2O_5 \cdot (NH_4)_2O \cdot 2\ H_2O + 58\ aq.$$

The arrangement of the constituents is here, of course, purely arbitrary, and must be regarded as only provisional. In the analyses above given the phosphoric oxide was determined directly and by double precipitation. The vanadic oxide was determined by boiling with chlorhydric acid and titrition, in the manner already described.

16 : 1 : 3 *Series.* — A boiling solution of ammonic meta-vanadate dissolves the white insoluble phospho-tungstates of ammonium quite readily to a very deep orange-red solution. After standing some

days, large deep orange or garnet-red crystals separate in quantity. They appear to be octahedra, and when first separated from the mother liquor are very beautiful; but on standing in the air they lose their lustre, perhaps from a superficial effervescence, and become dull red. The salt is readily soluble in water, giving a deep orange-red solution, and crystallizes from the solution unchanged. The constitution of this salt is represented by the formula,

$$16\ WO_3 \cdot 3\ V_2O_5 \cdot P_2O_5 \cdot 5\ (NH_4)_2O + 37\ aq,$$

as the following analyses show: —

1.0379 gr. lost on ignition with WO_4Na_2 0.1826 gr. = 17.59% NH_3 and H_2O
1.2811 gr. gave 0.1264 gr. NH_4Cl = 4.80% $(NH_4)_2O$
1.0652 gr. " 0.1074 gr. V_2O_5 = 10.08%
1.0130 gr. " 0.0419 gr. $P_2O_7Mg_2$ = 2.64% P_2O_5

The formula given requires: —

		Calc'd.		Found.	
16 WO_3	3712	69.67	82.62	69.69	82.41
3 V_2O_5	548	10.28		10.08	
P_2O_5	142	2.67		2.64	
5 $(NH_4)_2O$	260	4.88		4.80	
37 H_2O	666	12.50		12.79	
	5328	100.00		100.00	

Adopting the provisional hypothesis which I have proposed above, that V_2O_5 as $V_2O_2 \cdot O_3$ may partially replace MoO_3 or WO_3 in these combinations, and that, on the other hand, V_2O_5 also replaces P_2O_5, we may write the formula given above,

$$8\ WO_3 \cdot 2\ V_2O_2 \cdot O_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O + \\ 8\ WO_3 \cdot V_2O_5 \cdot 2\ (NH_4)_2O \cdot H_2O + 36\ aq,$$

in which formula the first term is reduced to the type of

$$10\ WO_3 \cdot P_2O_5 \cdot 3\ (NH_4)_2O.$$

The presence of five molecules of ammonic oxide shows that the salt belongs to the acid type so often met with in this class of compounds, and upon the view which I consider probable,* that the formulas of all the phospho-tungstates and phospho-molybdates as now received should be doubled, we should write the above formula

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* Proceedings, Vol. XVII. p. 89.

$$16\ WO_3 \,.\, 2\ V_2O_2 . O_3 . V_2O_5 . P_2O_5 \,.\, 5\ (NH_4)_2O \,.\, H_2O + 36\ aq;$$

corresponding to

$$16\ WO_3 \,.\, 2\ P_2O_5 \,.\, 5\ (NH_4)_2O \,.\, H_2O.$$

I consider this view of the subject as most probable in the present state of our knowledge.

60 : 3 : 2 *Series.* — When the 20 : 1 : 6 baric phospho-tungstate already described is boiled with vanadic hydrate, $VO(OH)_3$, the acid dissolves readily, and a beautiful orange-red solution is formed. On cooling, a salt separates in octahedral crystals, which have a very fine aurora-red color. The crystals dissolve rather easily in hot water, but are at the same time decomposed. A brownish orange salt then separates in distinct crystals, together with a white powder. The two can be separated mechanically. The mother liquor of the aurora-red salt yields on evaporation large dark-red crystals. Of the aurora-red salt,—

0.4165 gr.	lost on ignition with WO_4Na_2	0.0540 gr.	= 12.96%	
1.1550 gr.	“ “ “ “	0.1500 gr.	= 12.98%	
0.8819 gr.	gave of mixed oxides	0.6474 gr.	= 73.41%	
1.4699 gr.	“ “ “	1.0784 gr.	= 73.37%	
1.5188 gr.	“ “ “	1.1145 gr.	= 73.38%	
1.5188 gr.	“ of $P_2O_7Mg_2$	0.0508 gr.	= 2.14%	P_2O_5
1.0522 gr.	“ of mixed oxides	0.7709 gr.	= 73.26%	
1.0522 gr.	“ of $P_2O_7Mg_2$	0.0380 gr.	= 2.31%	P_2O_5
1.3324 gr.	“ of V_2O_5 by titrition	0.0258 gr.	= 1.93%	
0.2693 gr.	“ “ “	0.0051 gr.	= 1.87%	

The analyses correspond to the formula

$$60\ WO_3 \,.\, 3\ P_2O_5 \,.\, 2\ V_2O_5 \,.\, 18\ BaO + 144\ aq,$$

which requires : —

		Calc'd.		Mean.					
60 WO_3	13920	69.39	73.35	69.23	73.35	69.29	69.25	69.26	69.14
3 P_2O_5	426	2.14		2.22		2.14	2.31		
2 V_2O_5	366	1.82		1.90		1.93	1.87		
18 BaO	2754	13.73		13.68			13.68		
144 H_2O	2592	12.92		12.97		12.96	12.98		
	20058	100.00		100.00					

The baric oxide was determined by difference. In all determinations of the three acid oxides it was found necessary to ignite finally with a weighed quantity of normal sodic tungstate, in order to expel the mercuric oxide completely, and obtain a constant weight. The aurora-red salt may be regarded as a double compound, with the possible formula

$$3\,\{12\,WO_3\,.\,P_2O_5\,.\,4\,BaO\,.\,2\,H_2O\} + 2\,\{12\,WO_3\,.\,V_2O_5\,.\,3\,BaO\,.\,3\,H_2O\} + 132\text{ aq.}$$

It has, I believe, the highest molecular weight, 20058, yet observed, though I shall describe a little farther on a phospho-vanadio-vanadico-tungstate with the formula

$$60\,WO_3\,.\,3\,P_2O_5\,.\,V_2O_5\,.\,VO_2\,.\,18\,BaO + 150\text{ aq,}$$

with the molecular weight 20066. It will be interesting to determine the specific heats of bodies of this class, as well as the heat of formation. The formation of the aurora-red salt is very simply expressed by the equation,

$$3\,\{20\,WO_3\,.\,P_2O_5\,.\,6\,BaO\} + 2\,V_2O_5 = 60\,WO_3\,.\,3\,P_2O_5\,.\,2\,V_2O_5\,.\,18\,BaO,$$

the process being one of simple addition.

I have mentioned above the fact that a dark red salt crystallizes from the mother liquor of the aurora-red salt. The following analytical results were obtained with the small quantity of this salt at my disposal: —

0.7660 gr. gave 0.5570 gr. mixed oxides = 72.71%
1.0405 gr. " 0.2133 gr. SO_4Ba = 13.45% BaO
1.0405 gr. lost on ignition 0.1451 gr. = 13.94%

In the orange-brown salt formed by the decomposition of the aurora-red salt,

1.1919 gr. lost on ignition with WO_4Na_2 0.1611 gr. = 13.51%
1.0476 gr. gave 0.7653 gr. mixed oxides = 73.05%
1.4122 gr. " 0.3078 gr. SO_4Ba = 14.31%
1.2372 gr. " 0.0087 gr. V_2O_5 = 0.70%

No formulas can be deduced from these analyses, but they may serve to identify the salts analyzed in future investigations.

18 : 3 : 4 *Series.* — The 24 : 1 phospho-tungstate of sodium already described, $24\,WO_3\,.\,P_2O_5\,.\,2\,Na_2O\,.\,4\,H_2O + 23$ aq, is readily dissolved by boiling with a solution of ammonic meta-vanadate, and gives a deep orange-red liquid. This solution does not yield crys-

tals on evaporation, or after standing for some time. When, however, a solution of potassic bromide is added in large excess, a deep orange-red crystalline precipitate is quickly formed in large quantity. The salt exhibits the peculiar aurora-red tint which is often observed when phosphoric acid or a soluble phosphate is mixed with a solution containing both tungstic and vanadic oxides. The compound dissolves in a rather large proportion of hot water, but at the same time undergoes decomposition, and the solution after a time deposits a bright orange-brown crystalline salt without the peculiar aurora-red tint. The first-mentioned potassic salt, as precipitated from a cold solution, allowed to stand twenty-four hours, then washed with cold water and dried on woollen paper, gave on analysis the formula

$$18\ WO_3 \cdot 4\ V_2O_5 \cdot 3\ P_2O_5 \cdot 8\ K_2O + 32\ aq,$$

which may perhaps be written

$$2\ \{6\ WO_3 \cdot 2\ V_2O_5 \cdot P_2O_5 \cdot 3\ K_2O\} + 6\ WO_3 \cdot P_2O_5 \cdot 2\ K_2O \cdot H_2O,$$

the type of the first compound being

$$8\ WO_3 \cdot P_2O_5 \cdot 3\ K_2O.$$

1.1017 gr. lost on ignition with WO_4Na_2 0.0973 gr. = 8.83%
1.0803 gr. gave 0.8646 gr. mixed oxides = 80.03%
1.1159 gr. " 0.1218 gr. V_2O_5 = 10.91%
1.2104 gr. " 0.1227 gr. $P_2O_7Mg_2$ = 6.48%

The formula given requires: —

		Calc'd.		Found.	
18 WO_3	4176	62.68	80.06	62.64	80.03
4 V_2O_5	732	10.99		10.91	
3 P_2O_5	426	6.39		6.48	
8 K_2O	752	11.29		11.14	
32 H_2O	576	8.65		8.83	
	6662	100.00			

7 : 1 : 1 *Series.* — The bright orange-brown salt formed by the decomposition of the 18 : 4 : 3 salt was in small distinct granular crystals. Of this salt, —

0.9773 gr. lost on ignition with WO_4Na_2 0.0780 gr. = 7.98%
1.0160 gr. gave 0.8205 gr. mixed oxides = 80.76%
1.3077 gr. " 0.1037 gr. V_2O_5 = 7.93%
1.0113 gr. " 0.0958 gr. $P_2O_7Mg_2$ = 6.06% P_2O_5

The analyses correspond, though not very closely, to the formula

$$7\ WO_3 \,.\, V_2O_5 \,.\, P_2O_5 \,.\, 3\ K_2O + 11\ aq,$$

which requires:—

		Calc'd.		Found.	
7 WO_3	1624	66.86	80.23	66.77	80.76
V_2O_5	183	7.53		7.93	
P_2O_5	142	5.84		6.06	
3 K_2O	282	11.61		11.26	
11 H_2O	198	8.16		7.98	
	2429	100.00			

According to the view which I have taken as to the function of V_2O_5 in this class of compounds, the 7 : 1 : 1 potassic salt belongs to the type

$$8\ WO_3 \,.\, P_2O_5 \,.\, 3\ K_2O,$$

$V_2O_2 \,.\, O_3$ taking the place of one molecule of WO_3. A much more extended study will be necessary to test this hypothesis. The vanadio-phospho-tungstates are probably numerous, and from their great beauty, as well as from their theoretic interest, form an attractive subject for investigation. The following notes may serve to furnish fresh points of departure. When the solution of vanadio-tungstate of sodium (obtained by boiling 12 : 5 acid sodic tungstate with the mixed oxides of vanadium and oxidizing completely with bromine) is mixed with a solution of hydro-disodic phosphate, no apparent action takes place; but on boiling, the orange solution takes a deep red color, and soon deposits splendid ruby-red crystals in quantity. These crystals are decomposed in part even by cold water, which appears to separate phosphoric acid or sodic phosphate. An orange-colored sodium salt then separates. Almost exactly the same results are obtained when a solution of vanadio-tungstate of ammonium is boiled with a solution of ammonic phosphate. The liquid takes a beautiful deep red tint, and soon deposits splendid ruby-red crystals. The solution of the sodium salt, after a day or two, gives with one of trimethyl-ammonium chloride, $N(CH_3)_3HCl$, very fine granular ruby-red crystals. Of these crystals,

0.9752 gr. gave 0.8549 gr. mixed oxides = 87.66%
1.1543 gr. " 0.0631 gr. V_2O_5 = 5.46%
1.0061 gr. " 0.0552 gr. $P_2O_7Mg_2$ = 3.51%

The loss corresponding to water and trimethyl-ammonium oxide is 12.34%. The ratio of the three oxides, WO_3, V_2O_5, and P_2O_5, is

$34\ WO_3 \cdot 3\ V_2O_5 \cdot 2\ P_2O_5$; but a determination of the trimethyl-ammonium oxide will be necessary in order to settle the formula completely. I am indebted to the kindness of Prof. Arthur Michael for a supply of the trimethylamin salt, which has proved of great service to me. The disposition of the corresponding oxide to form well-crystallized salts makes it a valuable test, and it should become an article of commerce for chemists' use.

VANADIO-VANADICO-MOLYBDATES.

The salt about to be described constitutes the type of a new and extensive series of complex acids, which contain two different linking oxides, embraced respectively under the formulas R_2O_5 and $R'O_2$, in which, however, R and R′ may be identical. The general formula for this class of molybdenum compounds may be written

$$m\ MoO_3 \cdot n\ R_2O_5 \cdot p\ R'O_2 \cdot x\ R''_2O,$$

which, in the case of the identity of R and R′, becomes

$$m\ MoO_3 \cdot n\ R_2O_5 \cdot p\ RO_2 \cdot x\ R''_2O.$$

I shall show that these are corresponding salts, containing tungsten in place of molybdenum. Vanadio-vanadico-molybdates are very readily formed by boiling a mixture of the two oxides of vanadium with an acid molybdate; by the partial reduction of vanadio-molybdates; or by digesting solutions of acid molybdates with solutions which contain vanadic dioxide and pentoxide.

28 : 4 : 1 *Vanadio-vanadico-molybdate of Ammonium.* — When pure ammonic divanadate is ignited in an open platinum vessel, and the remaining mass is boiled with an excess of a solution of 14 : 6 acid ammonic molybdate, a greenish solution is formed, which after filtration and evaporation yields on cooling a pale greenish-yellow crystalline salt. After draining on the filter-pump, the salt may be redissolved and recrystallized, when it presents very distinct granular greenish-yellow crystals. The solution is bright yellow. Of this salt, —

1.4613 gr. lost on ignition with WO_4Na_2 0.2527 gr. = 17.29%
1.3326 gr. gave by titrition 0.1423 gr. $(NH_4)_2O$ = 10.68%
1.2031 gr. " " 0.1288 gr. " = 10.71%
2.1968 gr. " 0.2184 gr. V_2O_5 = 9.95% $VO_2 + V_2O_5$
0.9980 gr. " 0.0607 gr. VO_2 = 6.08% VO_2

The analyses lead to the formula

$$28\ MoO_3 \,.\, 4\ V_2O_5 \,.\, VO_2 \,.\, 11\ (NH_4)_2O + 20\ aq,$$

which requires: —

		Calc'd.	Found.	
$28\ MoO_3$	4032	73.56	73.34	
$4\ VO_2$	334	6.09	6.08	
V_2O_5	183	3.34	3.29	
$11\ (NH_4)_2O$	572	10.44	10.68	10.71
$20\ H_2O$	360	6.57	6.60	
	5481	100.00		

The compound is doubtless to be regarded as a double salt, but there are at present no data upon which to base even a conjectural arrangement. The salt is slightly soluble in cold water, the solution being strongly acid to litmus paper. It is soluble in hot water, and separates from the solution without sensible decomposition. The solution is reduced with great difficulty, either by sulphurous oxide or by sulphydric acid gas. For analysis I found it best, after oxidation with nitric acid, to boil with excess of ammonia, evaporate with ammonic chloride, and separate the ammonic meta-vanadate upon an asbestos filter. The vanadium was then determined by titrition with hypermanganate. The vanadic dioxide was determined by hypermanganate in the solution of the salt, after adding phosphoric and sulphuric acids. It was found necessary to use very dilute solutions, and the close agreement of the determination of vanadic dioxide with the formula cannot be regarded as other than accidental. The reactions of this salt are as follows: the cold dilute solution gives no precipitate with salts of zinc, copper, manganese, and cadmium; a pale yellow flocky precipitate with baric chloride, which soon becomes granular-crystalline; with potassic bromide, after some days, very fine, large prismatic crystals; with argentic nitrate, the solution gives a flocky precipitate, which is yellow with a tinge of buff; with mercurous nitrate, a bright, and with thallous nitrate, a pale yellow, flocky precipitate.

15 : 1 : 2 *Vanadio-vanadico-molybdate of Barium.* — Baric chloride added to the mother liquor from which the preceding salt was prepared gave a pale yellow crystalline, and, so far as could be seen, homogeneous precipitate, in very small grains. This was filtered off, well washed with cold water, and dried on woollen paper for analysis. The filtrate was greenish, and gave no other salt on evapo-

ration. The barium salt is very slightly soluble in cold water, and is decomposed by boiling water, with separation of baric molybdate, and formation of a pale greenish-yellow solution, which possibly contains a new salt of the same class. The salt is decomposed by boiling with mercurous nitrate, giving a bright yellow crystalline body. Boiled with argentic nitrate it gives an orange-colored precipitate, which is also crystalline. Of this salt, —

1.1690 gr. gave 0.7260 gr. $WO_3 + V_2O_5 + VO_2$ = 62.09%
and 0.4772 gr. SO_4Ba = 26.80% BaO
1.5526 gr. gave 0.6332 gr. " = 26.70% "
1.0341 gr. lost on ignition 0.1127 gr. = 10.90% H_2O
2.1990 gr. gave by titrition 0.1748 gr. = 7.95% V_2O_5

The titrition was effected by $SO_4H_2 + SO_4(NH_4)_2 + 6$ aq, in a solution to which HCl had been added, after oxidation with nitric acid and addition of an excess of sodic carbonate. All the vanadium present was therefore estimated as V_2O_5.

The analyses correspond closely to the formula

$$30\ MoO_3\ .\ 2\ V_2O_5\ .\ 3\ VO_2\ .\ 14\ BaO + 48\ aq,$$

which requires: —

		Calc'd.	Found.	
30 MoO_3	4320	54.40	54.40	(diff.)
2 V_2O_5	366	4.62	4.73	
3 VO_2	249	3.13	3.22	
14 BaO	2142	26.97	26.70	26.80
48 H_2O	864	10.88	10.90	
	7941	100.00		

The compound is doubtless a double salt, and its formula may perhaps be

$$2\ \{6\ MoO_3 . V_2O_5 . 4\ BaO . 2\ H_2O\} + 3\ \{6\ MoO_3 . VO_2 . 2\ BaO . 4\ H_2O\} + 32\ aq;$$

only it must be remarked that the empirical formula given above must be doubled in order to obtain a symmetrical structural formula, as the number of molecules of vanadic dioxide is uneven in the simpler expression given.

VANADIO-VANADICO-TUNGSTATES.

The class of salts to which I have given this name come also under the general formula

$$m\,RO_3\,.\,n\,R'_2O_5\,.\,p\,R''O_2\,.\,x\,R'''_2O,$$

and constitute, like the corresponding compounds containing molybdenum, a new ternary series. They are formed under the same conditions as these last, and like these have an orange or orange-red color, with a more or less distinct tinge of green.

12 : 2 : 3 (?) *Vanadio-vanadico-tungstate of Sodium.* — This salt, which was the first which I obtained containing vanadium, was formed by boiling with 12 : 5 acid sodic tungstate, a commercial vanadic pentoxide, which I owed to the kindness of Dr. J. Lawrence Smith, and which was probably prepared by igniting ammonic meta-vanadate, and therefore contained a certain proportion of vanadic dioxide. I did not succeed in preparing it a second time with a new preparation of the mixed oxides, and therefore trust that the incomplete analyses and meagre description of this and the corresponding ammonium and silver salts will be excused. The solution of the mixed oxides in the acid tungstate gave a deep orange-red solution, which, on evaporation to the consistency of a syrup, yielded after a time large orange-red apparently triclinic crystals, extremely soluble in water, and crystallizing only from syrupy solutions. In this salt, twice recrystallized, —

0.5968 gr. lost on ignition to fusion of the residue 0.1019 gr. = 17.07%
0.6852 gr. " " " " 0.1164 gr. = 16.99%
0.3311 gr. gave 0.2481 gr. $WO_3 + V_2O_5 + VO_2$ = 74.96%

These analyses, taken in connection with those of the ammonium and silver salts, may, with at least a certain degree of probability, be considered as leading to the formula

$$12\ WO_3\,.\,2\ V_2O_5\,.\,3\ VO_2\,.\,6\ Na_2O + 43\ aq,$$

which requires: —

		Calc'd.	Found.	
12 WO_3	2784	74.79	74.96	
2 V_2O_5	366			
3 VO_2	249			
6 Na_2O	372	8.18	8.05	
43 H_2O	774	17.03	16.99	17.07
	4545	100.00		

The solution of this salt had a deep orange-red color with distinct greenish reflections. Bromine water instantly gave a very fine deep orange solution, having nearly the color of potassic dichromate, and without the greenish tint: the liquid then contained only a sodic vanadio-tungstate. The solution gave flocky precipitates with various salts of heavy metallic oxides, and a bright red crystalline precipitate with argentic nitrate. A solution of acid potassic tungstate dissolved the mixture of oxides of vanadium, forming a greenish-orange solution, which also became bright orange-red with bromine. The potassic salt crystallized from this solution after evaporation to the consistency of a syrup, and gave crystals of a peculiar greenish-orange tint. The solution of this salt gave a bright orange indistinctly crystalline precipitate with mercurous nitrate. This precipitate was decomposed by dilute chlorhydric acid, yielding a yellow solution from which no crystals were obtained by evaporation. This is perhaps the acid of the series.

12 : 2 : 3 (?) *Ammonium Salt.* — 12 : 5 acid ammonic tungstate was boiled with a portion of the same commercial vanadic oxides in excess. The oxides dissolved readily, leaving, as in the cases of the sodium and potassium salts, a quantity of a black insoluble powder. The deep orange-yellow solution deposited on cooling beautiful orange-colored crystals of an ammonium salt; but on evaporating the main solution *in vacuo*, two kinds of crystals were obtained, one in relatively large dark-red octahedrons, the other much lighter-colored and resembling potassic dichromate. The darker salt gave in two analyses 17.98 and 18.05 % of water and ammonic oxide. Of the lighter-colored salt separated mechanically from the first-named, —

0.8429 gr. lost on ignition	0.1149 gr.	= 13.63 %	H_2O and NH_3
0.8164 gr. " "	0.1107 gr.	= 13.56 %	" "
0.9047 gr. gave	0.1502 gr. NH_4Cl	= 8.07 %	$(NH_4)_2O$

The analyses agree, so far as they go, very well with the formula,

$$12\ WO_3\ .\ 2\ V_2O_5\ .\ 3\ VO_2\ .\ 6\ (NH_4)_2O + 12\ aq,$$

which requires: —

		Calc'd.	Found.
$12\ WO_3$	2784	86.55	86.41 (diff.)
$2\ V_2O_5$	366		
$3\ VO_2$	249		
$6\ (NH_4)_2O$	312	7.94	8.07
$12\ H_2O$	216	5.51	5.52
	3927	100.00	

The solution of this salt gives a beautiful scarlet precipitate with argentic nitrate, and a fine yellow precipitate with salts of strychnin, which after standing some hours becomes granular crystalline.

12 : 2 : 3 (?) *Vanadio-vanadico-tungstate of Silver.* — The salt analyzed was in beautiful scarlet crystals, and was prepared by precipitating the ammonium salt with argentic nitrate, and washing with cold water. The salt is not distinctly crystalline when first thrown down, but becomes so after standing in the liquid. It is very slightly soluble in cold water, but dissolves in much hot water to a yellow liquid. Of this salt, —

2.1193 gr. lost on ignition 0.0621 gr. = 2.93%
0.7511 gr. gave 0.7420 gr. AgCl = 28.21% Ag_2O

These analyses agree with the formula,

$$12\ WO_3 \,.\, 2\ V_2O_5 \,.\, 3\ VO_2 \,.\, 6\ Ag_2\ O + 8\ aq,$$

which requires: —

		Calc'd.	Found.
12 WO_3	2784		
2 V_2O_5	366	68.87	68.86 (diff.)
3 VO_2	249		
6 Ag_2O	1392	28.21	28.21
8 H_2O	108	2.92	2.93
	4935	100.00	

The analyses which I have given may not be considered as sufficiently complete to establish the formulas assigned, but they serve to prove the existence of at least one class of vanadio-vanadico-tungstates. In substances of such high molecular weights the agreement between the formulas of three different salts prepared under precisely the same conditions has a certain value, but it is less conclusive than when the molecular weight is lower, because such a change as is produced by writing, for instance, 2 VO_2 for V_2O_5, does not greatly affect the percentage results. If we admit the correctness of the formulas given, it will still be necessary to double them in order to construct a structural formula which shall be symmetrical, since the number of molecules of VO_2, either free or contained in V_2O_5, is uneven. For the complete analysis of compounds of this class it will be most advantageous to determine the vanadic pentoxide by heating with strong chlorhydric acid in the manner already indicated, and then to determine the dioxide in another portion by means of hypermanganate, if possible, or by first oxidizing with bromine, and then determining the whole of the vanadium as pentoxide by boiling with chlorhydric acid and titrating as before.

PHOSPHO-VANADIO-VANADICO-TUNGSTATES.

I have given this rather ponderous appellation to a class of compounds in which vanadium exists partly as pentoxide and partly as dioxide. They may be regarded simply as double salts, but in the present state of our knowledge it will be found most convenient to consider them as a special class.

Salts of this type are formed whenever phospho-tungstates are mixed with vanadates in presence of vanadic dioxide, when vanadio-vanadico-tungstates are heated with solutions of alkaline phosphates or with phosphoric acid, and when phospho-vanadates and alkaline tungstates are brought together in presence of a reducing agent and of an acid. The salts are sometimes green and sometimes orange-red. In the last case they have frequently the peculiar aurora-red tint noticed among the colors of the phospho-vanadio-tungstates. They pass readily by oxidation with bromine or nitric acid into salts of the last-mentioned type, and they may be also derived from these by a partial reduction of the vanadic pentoxide.

Analytical Methods. — These are essentially the same as those which have been described. All the non-basic oxides may be determined together by means of mercurous nitrate and mercuric oxide, after complete oxidation with nitric acid. Phosphoric oxide may usually be determined directly, or after separation of a non-alkaline base, by double precipitation with magnesia-mixture. The vanadic pentoxide can be estimated by boiling with chlorhydric acid and titrition in the manner already pointed out. To determine the vanadic dioxide the solution must first be oxidized completely, so as to convert the dioxide into pentoxide, any excess of the oxidizing agent employed being carefully removed. I prefer to use bromine water for this purpose. The whole of the vanadium may then be determined by titrition as above. The difference between the amount of vanadic pentoxide found before and after complete oxidation then gives, by a simple proportion, the corresponding amount of vanadic dioxide. It must be remembered that the sum of the non-basic oxides found by the mercury process requires to be corrected by adding the amount of oxygen required to convert the vanadic dioxide present into the equivalent of pentoxide. When the whole quantity of vanadium present is small, this correction may be neglected, as falling within the limits of the errors of analysis unavoidable with our present methods. Baric oxide in these salts is best estimated by difference, as the direct estimation almost always gives too high a percentage.

60 : 3 : 1 : 1 *Barium Salt.* — When ammonic vanadate is heated in a porcelain crucible until all the ammonia is expelled, the greenish residue consists, as already stated, chiefly of a mixture of vanadic dioxide and pentoxide. If this mixture be added in small portions at a time to a boiling solution of the baric phospho-tungstate, $20\ WO_3 \cdot P_2O_5 \cdot 6\ BaO$, already described, the liquid takes at once a rather dull green color. The filtrate from the excess of mixed oxides, after evaporation in a water-bath and standing for some hours, yields a mass of deep green crystals, mechanically mixed with a relatively small proportion of a fine white powder, which may easily be removed by washing with cold water and pouring off the powder in suspension. The dark green crystals are regular octahedrons, frequently in long aggregates and beautifully defined. The salt is rather insoluble in cold but readily soluble in hot water, with a dark and rather dull green color. The cold solution, after adding dilute sulphuric acid, is not sensibly oxidized by potassic hypermanganate or in alkaline solution by iodine. The hot solution is oxidized by bromine and by nitric acid, and becomes deep orange-red. At a boiling heat potassic hypermanganate also oxidizes it, the quantity required for oxidation being very small, so that it can with difficulty be estimated. Of this salt, —

1.2596 gr.	gave	0.9178 gr. mixed oxides	= 72.86%	
1.0160 gr.	lost on ignition	0.1362 gr.	= 13.40%	
1.4649 gr.	“ “	0.1969 gr.	= 13.44%	
1.8580 gr.	gave	0.0624 gr. $P_2O_7Mg_2$	= 2.15%	P_2O_5
1.3846 gr.	“	0.0105 gr. V_2O_5	= 0.76%	
1.1972 gr.	“	0.0131 gr. “	= 1.09%	

In these analyses the vanadic pentoxide was determined directly in the salt, by boiling with chlorhydric acid and titrating. In two other analyses, the vanadic dioxide was first completely oxidized by means of bromine; the whole quantity of vanadium was then determined as before. The percentage of vanadic dioxide was then calculated from the excess of V_2O_5 over that found by direct analysis. In this process, —

1.1379 gr.	gave	0.0161 gr. V_2O_5	= 1.44%
1.1714 gr.	“	0.0200 gr. “	= 1.71%

The analyses correspond very closely to the formula,

$$60\ WO_3 \cdot 3\ P_2O_5 \cdot V_2O_5 \cdot VO_2 \cdot 18\ BaO + 150\ aq,$$

which requires: —

		Calc'd.	Found.	
60 WO_3	13920	69.37	69.32	
3 P_2O_5	426	2.12	2.15	
V_2O_5	183	0.92	1.09	0.76
VO_2	83	0.42	0.46	
18 BaO	2754	13.72	13.72	
150 H_2O	2700	13.45	13.40	13.44
	20066	100.00		

The baric oxide is estimated by difference. The relation of this salt to the aurora-red octahedral phospho-vanadio-tungstate of barium already described is interesting. We have respectively the formulas,

$$60\ WO_3 \cdot 3\ P_2O_5 \cdot V_2O_5 \cdot V\ O_2\ \cdot 18\ BaO + 150\ aq,$$
$$60\ WO_3 \cdot 3\ P_2O_5 \cdot V_2O_5 \cdot V_2O_5 \cdot\ 18\ BaO + 144\ aq,$$

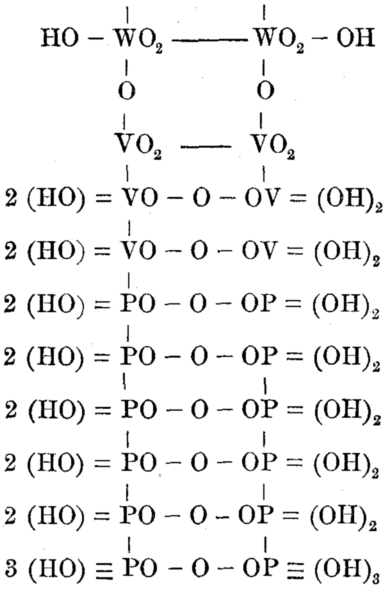
and it is easy to see how, at least theoretically, one salt could be prepared from the other. With respect to the rational constitution of the green salt, it is possible at present only to form a provisional hypothesis. I am disposed to regard it as a triple compound, and to assign to it the formula,

$$3\ \{12\ WO_3 \cdot P_2O_5 \cdot 3\ BaO \cdot 3\ H_2O\} + 12\ WO_3 \cdot V_2O_5 \cdot 5\ BaO \cdot H_2O + 12\ WO_3 \cdot VO_2 \cdot 4\ BaO$$

In this formula all the terms correspond to known compounds, the last to the dodeka-silico-tungstate type established by Marignac, VO_2 replacing SiO_2. Of course, as in similar cases, various other formulas may be proposed. I lay no particular stress upon the view I have taken, which a wider and deeper study of these compounds may prove to be untenable. The formation of the salt may be expressed by the equation,

$$3\ \{20\ WO_3 \cdot P_2O_5 \cdot 6\ BaO\} + V_2O_5 + VO_2 = 60\ WO_3 \cdot 3\ P_2O_5 \cdot V_2O_5 \cdot VO_2 \cdot 18\ BaO.$$

The formula must be doubled to permit of a representation by means of a symmetrical structural formula. If we omit all the molecules of tungstic oxide except two, in order to save space, the linking portion of the structural formula of the corresponding acid may be written as follows: —



$$\begin{array}{rcccccl}
 & & | & & | & & \\
 & \mathrm{HO} - & \mathrm{WO_2} & \text{———} & \mathrm{WO_2} & - \mathrm{OH} & \\
 & & | & & | & & \\
 & & \mathrm{O} & & \mathrm{O} & & \\
 & & | & & | & & \\
 & & \mathrm{VO_2} & \text{——} & \mathrm{VO_2} & & \\
 & & | & & | & & \\
2\,(\mathrm{HO}) & = & \mathrm{VO} & - \mathrm{O} - & \mathrm{OV} & = & (\mathrm{OH})_2 \\
 & & | & & & & \\
2\,(\mathrm{HO}) & = & \mathrm{VO} & - \mathrm{O} - & \mathrm{OV} & = & (\mathrm{OH})_2 \\
 & & | & & & & \\
2\,(\mathrm{HO}) & = & \mathrm{PO} & - \mathrm{O} - & \mathrm{OP} & = & (\mathrm{OH})_2 \\
 & & | & & & & \\
2\,(\mathrm{HO}) & = & \mathrm{PO} & - \mathrm{O} - & \mathrm{OP} & = & (\mathrm{OH})_2 \\
 & & | & & | & & \\
2\,(\mathrm{HO}) & = & \mathrm{PO} & - \mathrm{O} - & \mathrm{OP} & = & (\mathrm{OH})_2 \\
 & & | & & | & & \\
2\,(\mathrm{HO}) & = & \mathrm{PO} & - \mathrm{O} - & \mathrm{OP} & = & (\mathrm{OH})_2 \\
 & & | & & | & & \\
2\,(\mathrm{HO}) & = & \mathrm{PO} & - \mathrm{O} - & \mathrm{OP} & = & (\mathrm{OH})_2 \\
 & & | & & | & & \\
3\,(\mathrm{HO}) & \equiv & \mathrm{PO} & - \mathrm{O} - & \mathrm{OP} & \equiv & (\mathrm{OH})_3
\end{array}$$

This formula, which, like most of those which I have given, is purely conjectural, will at least serve to show how the two different states of oxidation of vanadium may be represented in the combination, and how the basicity of PO and VO may be affected by their position. Such formulas are not without value, as suggesting the possibility of forming new combinations, even if, as I prefer in this case to do, we consider the salt represented as double or triple. Structural formulas for double and still more for triple inorganic salts would probably be still more complex, and what I have aimed at is to show how all the valences may be satisfied in an arbitrarily selected compound containing four oxides of three different types.

The general results deducible from the formulas which I have given in the present instalment of my work are as follows:—

1. Hypophosphorous and phosphorous acids may enter into combination with tungstic and molybdic oxides as links, so as to form complex inorganic acids. The structure of these four classes of acids indicates the possibility of forming new series of acids, in which methyl and other organic radicals or residues may take the place of the constitutional hydrogen of the hypophosphorous and phosphorous

linking terms, and again of others in which, besides the replacement of hydrogen, phosphorus may be replaced by arsenic, and possibly by antimony and other elements.

2. Vanadium may replace phosphorus and arsenic so as to form well-defined series of vanadio-molybdates and vanadio-tungstates embraced under the general formula

$$m\,RO_3 \,.\, n\,V_2O_5 \,.\, p\,R^1{}_2O.$$

3. Vanadic and phosphoric pentoxides may enter simultaneously into combination with tungstic or molybdic oxide, so as to form classes of triple acids embraced under the general formula

$$m\,RO_3 \,.\, n\,P_2O_5 \,.\, p\,V_2O_5 \,.\, v\,H_2O.$$

4. A class of quadruple acids exists into which, in addition to phosphoric and vanadic pentoxides, vanadic dioxide may enter, the general formula being

$$m\,RO_3 \,.\, n\,P_2O_5 \,.\, p\,V_2O_5 \,.\, r\,VO_2 \,.\, v\,H_2O.$$

5. In another class of ternary or triple acids molybdic or tungstic oxide may be combined with both vanadic pentoxide and vanadic dioxide, the general formula being

$$m\,RO_3 \,.\, n\,V_2O_5 \,.\, p\,VO_2 \,.\, v\,H_2O.$$

I shall show hereafter that all of these results are capable of further generalization; that, for example, other oxides of the types RO_2 corresponding to hydrates of the form $R(OH)_4$ may replace VO_2 or $V(OH)_4$; that other pentoxides may replace P_2O_5, As_2O_5, and V_2O_5, either in the presence or in the absence of oxides of the type RO_2; in short, that the complex inorganic acids form a new department of inorganic chemistry, and not a series of isolated compounds.

(*To be continued.*)

XVIII.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

THE VOLUMETRIC DETERMINATION OF COMBINED NITROUS ACID.

By Leonard P. Kinnicutt and John U. Nef.

Presented May 9th, 1883.

The amount of nitrous acid contained in commercial samples of potassic and sodic nitrites has been commonly determined in the following manner. The nitrites are dissolved in slightly acidulated water; a solution of potassic permanganate is added till the oxidation of the nitrous acid is nearly completed; the solution is then made strongly acid, and potassic permanganate added until the solution has a faint red color.

This method is far from satisfactory, closely agreeing results being rather the exception than the rule. The cause is most probably due to the escape of a small amount of nitrous acid, and also to the slow oxidation of the last traces of the nitrous acid by the potassic permanganate.

A further study of the analyses of nitrites volumetrically seemed desirable, and after numerous experiments the following process, or modification of the old process, as it might more properly be called, was devised.

The sample of nitrite is dissolved in cold water, one part of the salt to at least three hundred parts of water. To this solution a deci-normal solution of potassic permanganate is added, drop by drop, till the liquid has a decided and permanent red color, then two or three drops of dilute sulphuric acid, and immediately afterwards an excess of the potassic permanganate solution. The liquid, which should now be of a dark red color, is made strongly acid with sulphuric acid, heated to boiling, and the excess of potassic permanganate determined by means of a deci-normal solution of oxalic acid.

Analyses of samples of both potassic and sodic nitrites, made in accordance with the above modification, show that results agreeing very closely with one another can easily be obtained.

Potassic Nitrite Solution.

[One litre contained 4.3550 grammes.]

Taken.		KNO_2 found.	
25 c.c. = 0.1089	gramme	0.09194 gramme =	84.44 %
35 c.c. = 0.1525	"	0.1289 "	84.48 %
40 c.c. = 0.1742	"	0.1472 "	84.51 %
55 c.c. = 0.2395	"	0.2024 "	84.49 %
60 c.c. = 0.2613	"	0.2210 "	84.53 %

Sodic Nitrite Solution.

[One litre contained 3.090 grammes.]

Taken.		$NaNo_2$ found.	
25 c.c. = 0.0919	gramme	0.07713 gramme =	83.95 %
35 c.c. = 0.1287	"	0.1082 "	84.07 %
45 c.c. = 0.1654	"	0.1390 "	84.05 %
53 c.c. = 0.1949	"	0.1639 "	84.03 %
60 c.c. = 0.2206	"	0.1854 "	84.05 %

The volumetric method for the determination of sulphites is also most unsatisfactory. The study of this subject was therefore given to Mr. R. Penrose, a student in this laboratory. He experimented both with potassic permanganate and oxalic acid as above, and also with iron alum and the permanganate; but, although many variations of these processes were tried, and the work carefully conducted, the results were unsatisfactory.

XIX.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

THE β PHENYLTRIBROMPROPIONIC ACID.

By Leonard P. Kinnicutt and George M. Palmer.

Presented May 9th, 1883.

The α phenyltribrompropionic acid and the products formed when this acid is decomposed by boiling water were briefly described by one of us last year.* During the past winter the study of the β acid was undertaken, and it has been considered best to give at this time the results so far obtained, as the further investigation must be carried on in different relations.

The β phenyltribrompropionic acid was obtained by the action of dry bromine on β monobromcinnamic acid, this last having been prepared in the way previously described.†

By the action of bromine on β monobromcinnamic acid, Glaser‡ obtained an acid, which he describes as melting during the absorption of the bromine and only solidifying again after several days. The melting point he found to be 45–48° C. The results obtained by us are very different. Perfectly pure β monobromcinnamic acid melting at 120° C. was placed under a bell glass with the theoretical amount of bromine. Not the slightest indication of melting was observed, and after twenty-four hours the bromine was all absorbed. The acid so obtained was purified by crystallization from chloroform and melted at 151° C. It is soluble in alcohol, ether, carbonic disulphide, chloroform, and benzol.

The analyses gave the following results: —

1. 0.2711 gr. substance gave 0.2788 gr. CO_2 and 0.0454 gr. H_2O.
2. 0.3845 gr. substance gave 0.3912 gr. CO_2 and 0.0702 gr. H_2O.
3. 0.1894 gr. substance gave 9.2769 gr. AgBr.
4. 0.1839 gr. substance gave 0.2696 gr. AgBr.

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* Kinnicutt, Amer. Chem. Jour., iii. 4.

† Ibid.

‡ Annalen der Chemie, cxliii. 339.

Calculated for $C_9H_7Br_3O_2$.		Found.			
		1.	2.	3.	4.
C	27.9	28.04	27.73		
H	1.8	1.86	2.00		
Br	62.17			62.24	62.40

Decomposition of the β Phenyltribrompropionic Acid by Water heated to 100° C.

Twenty grammes of the acid were placed in a flask with two hundred cubic centimeters of boiling water. Decomposition began immediately, a volatile oil separating out, which at the end of eight hours had for the greater part been carried over with the steam, leaving a clear liquid that on cooling deposited a white crystalline substance. On examination, the oil was found to be a dibromstyrol, the white crystalline substance the α monobromcinnamic acid, and a third substance, which remained in solution in the liquid, gave on analysis results corresponding very closely to those required for a phenyldibromlactic acid.

Dibromstyrol, $C_8H_6Br_2$.

The oil that was carried over by the steam was separated from the water by ether, and, after thorough washing to remove all traces of hydrobromic acid, the ether was distilled off. The oil thus obtained was of a light amber color, growing gradually darker, and giving off on long standing traces of hydrobromic acid.

It boils at 253–254° C. with slight decomposition, hydrobromic acid being formed.

The analyses of the oil, dried over sulphuric acid, gave the following results: —

1. 0.2518 gr. substance gave 0.3328 gr. CO_2 and 0.0518 gr. H_2O.
2. 0.3592 gr. substance gave 0.4810 gr. CO_2 and 0.0744 gr. H_2O.
3. 0.2518 gr. substance gave 0.3615 gr. AgBr.
4. 0.3032 gr. substance gave 0.4379 gr. AgBr.

Calculated for $C_8H_6Br_2$.		Found.			
		1.	2.	3.	4.
C	36.64	36.02	36.50		
H	2.29	2.26	2.30		
Br	61.06			61.10	61.40

The properties of this oil correspond in all respects with those of the dibromstyrol obtained from the decomposition of the α phenyltribrompropionic acid,* and it seems most probable that the two substances are not simply isomeric, but identical. This point, however, cannot be positively settled till a careful study has been made of the addition products of both compounds.

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* Kinnicutt, Amer. Chem. Jour., iii. 4.

α *Monobromcinnamic Acid.*

The nearly clear liquid from which the bromstyrol had been distilled was made slightly alkaline with sodic carbonate, and shaken with ether to remove the last traces of the oil. The solution was then evaporated to a volume of about one hundred cubic centimeters and acidified with dilute hydrochloric acid. A white precipitate was thrown down, which after one crystallization from boiling water melted at 132° C., and proved to be the α monobromcinnamic acid.

Two bromine determinations gave the following results: —

1. 0.1986 gr. substance gave 0.1661 gr. AgBr.
2. 0.2242 gr. substance gave 0.1874 gr. AgBr.

Calculated for $C_9H_7BrO_2$.		Found.	
		1.	2.
Br	35.25	35.58	35.56

The barium salt, formed by adding baric chloride to a dilute solution of the acid in warm water, resembled in every respect the barium salt of α monobromcinnamic acid as described by Glaser.[*] It was only slightly soluble in cold water and insoluble in alcohol. The barium salt of the β bromcinnamic acid is hygroscopic, and soluble in alcohol.

The salt gave on analysis the following result: —

0.3092 gr. substance gave 0.1233 gr. $BaSO_4$.

Calculated for $(C_9H_6BrO_2)_2Ba$.		Found.
Ba	23.23	23.42

The formation of the α monobromcinnamic acid from both the α and β phenyltribrompropionic acids was rather to be expected, as Glaser has found that the β monobromcinnamic acid is changed into the α by distillation, or by heating it with hydriodic acid,[†] and, moreover, Barish has shown that from both the α and β acids only the ethyl ether of the α acid can be obtained.[‡]

In speaking of these acids we have used the nomenclature proposed by Glaser. For although it is very probable that his α acid is in fact the β, it does not seem desirable to change names that have become familiar until it is absolutely necessary; and notwithstanding the work that has been done in the investigation of these acids during the past five years, no direct proof has been given as to the position of the bromine atoms.

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[*] Annalen der Chemie, cxliii. 334.

[†] Ibid., 336.

[‡] Jour. fur Prakt. Chemie, cxxviii. 185.

Phenyldibromlactic Acid.

On evaporating the filtrate from the α monobromlactic acid to a small volume, a substance crystallized out that melted at about 180° C. After recrystallization several times from water, the melting point rose to 184° C., and it gave on analysis amounts of carbon, hydrogen, and bromine corresponding to those required for a phenyldibromlactic acid.

The acid is very soluble in water, alcohol, and ether, soluble in chloroform, and slightly soluble in carbonic disulphide and benzol.

We have not as yet succeeded in obtaining the acid in large enough quantities to study its salts, or to decide which of the several possible formulas correctly represents its structure.

The analyses gave the following results: —

1. 0.1854 gr. substance gave 0.2257 gr. CO_2 and 0.0440 gr. H_2O.
2. 0.1989 gr. substance gave 0.2440 gr. CO_2 and 0.0470 gr. H_2O.
3. 0.1605 gr. substance gave 0.1870 gr. AgBr.
4. 0.1812 gr. substance gave 0.2122 gr. AgBr.

Calculated for $C_9H_8Br_2O_3$.		Found.			
		1.	2.	3.	4.
C	33.34	33.21	33.42		
H	2.46	2.63	2.62		
Br	49.37			49.60	49.70

Action of Bromine on Dibromstyrol.

The dibromstyrol obtained from the decomposition of the β phenyltribrompropionic acid was placed under a bell glass, with an excess of bromine. The oil gradually thickened, and after two days had absorbed about its own weight of bromine. It was then placed over quicklime, and after remaining there three or four days was washed thoroughly with water, and then separated from the water by shaking with ether. The so purified oil gave on analyses the following amounts of bromine: —

1. 0.2050 gr. substance gave 0.3646 gr. AgBr.
2. 0.2110 gr. substance gave 0.3737 gr. AgBr.
3. 0.2055 gr. substance gave 0.3651 gr. AgBr.

Calculated for $C_8H_6Br_4$.		Found. 1.	2.	3.
Br	75.82	75.68	75.34	75.60

The substance is evidently a tetrabromstyrol. It is a thick viscous oil, soluble in alcohol, ether, and carbonic disulphide. It begins to decompose on heating at a comparatively low temperature.

It is to be hoped that the study of the products formed by the action of boiling water or dilute alkalies on the above compound, and also on the substance obtained by the addition of bromine to the dibromstyrol formed from the *α* phenyltribrompropionic acid, will show not only the structure of the two dibromstyrols, but also of the two monobromcinnamic acids.

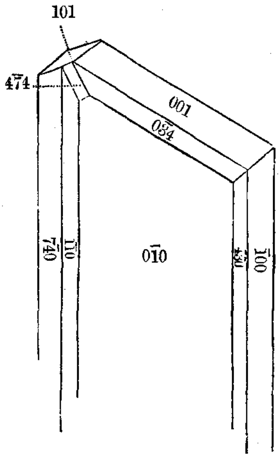
XX.

CONTRIBUTIONS FROM THE CHEMICAL LABORATORY OF HARVARD COLLEGE.

ON THE CRYSTALLINE FORM OF CHLORDIBROMACRYLIC ACID, $C_3ClBr_2O_2H_2$.

By Oliver W. Huntington, *Assistant.*

Presented May 9th, 1883.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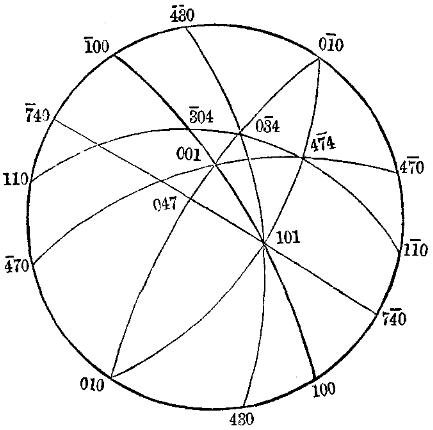
47̄4
001
03̄4
7̄40
110
01̄0
4̄30
1̄00


4̄30
1̄00
01̄0
7̄40
3̄04
03̄4
001
47̄4
47̄0
110
047
101
11̄0
4̄70
74̄0
010
100
430

These crystals were measured at the request of Dr. C. F. Mabery, who will describe their preparation in another connection. They are prismatic, and have the well-marked triclinic habit shown by the above free-hand sketch, while the accompanying stereographic projection gives more accurately the relations of the planes.

The chief prismatic axis is taken as the axis of *Z*, and the axes of the only other zones around which accurate measurements could be obtained were selected as the axes *X* and *Y*. The fundamental angles measured were:—

010	on	100	66° 23′
100	“	001	116° 17′
010	“	001	116° 20′
100	“	101	63° 50′
100	“	11̄0	47° 5′

From these we calculate

X on Y 104° 43′ Y on Z 71° 6′ X on Z 71° 10′

$$a : b : c = 0.7981 : 1 : 0.7207$$

In addition to the above, selected as fundamental planes, we also observed

$430;\ 0\bar{3}4;\ \bar{3}04?\ 7\bar{4}0;\ \bar{4}70;\ 4\bar{7}4;\ 047?$

These symbols were for the most part deduced from the zone intersections, and the indices could only in a few cases be verified by angular measurements. The faces of the vertical prism especially were very irregular, in consequence of the alternations caused by parallel grouping, so common with artificial crystals; and although the relative position of the fundamental planes could be accurately fixed, the symbols of the intermediate planes must be regarded as doubtful; these planes were seldom seen, and only in the vertical zone. The symbols given on the projection were obtained by finding the intersection with the vertical zone of other zones never well defined on the same crystal, and it can only be claimed that the approximate angular measurements on the vertical zone were compatible with the indices given. The following additional angles were calculated and verified by measurements when possible.

			Calculated.	Measured.
100	on	430	23° 52′	
100	"	$7\bar{4}0$	27° 5′	27°
010	"	$\bar{4}70$	42° 36′	42° 26′
$00\bar{1}$	"	$0\bar{3}4$	21°	21°

XXI.

ON A METHOD OF DETERMINING THE INDEX ERROR OF A MERIDIAN CIRCLE, AT ANY INSTANT, DEPENDING UPON THE OBSERVED POLAR DISTANCE OF POLARIS.

By William A. Rogers.

Presented May 9th, 1883.

The three methods which are commonly employed in the determination of the index error of a meridian circle are the following: —

(*a*.) The reading of the circle for the nadir point determined by the coincidence of the real and the reflected images of the central thread of the transit-reticule formed by reflection from the surface of mercury. This reading, which is a function of the latitude, will give the index error under the name of the "zenith-point correction."

(*b*.) The mean of the observed zenith distances of fundamental stars situated symmetrically with respect to the zenith, when compared with the corresponding tabular zenith distances, will yield the zenith-point correction independent of the refraction of the stars observed, since,

For stars south of the zenith, $z = (\phi - \delta) -$ Refraction,

and

For stars north of the zenith, $z = -(\phi - \delta) +$ Refraction.

(*c*.) A comparison of the observed with the tabular polar distances of fundamental stars symmetrically distributed in declination from the pole to a point as far south as the refraction can be securely determined, will give the index error under the form of a polar-point correction. The index error determined in this way, however, involves the systematic errors in declination of the fundamental system through which the observations are reduced. On the other hand, if the fundamental system is really free from this class of errors, this method furnishes the data for an approximate determination of the periodic errors of the circle.

At Washington, and at most other first-class observatories, the first method is employed. At Greenwich, both the first and the second methods are in use, the value adopted for any day being the mean result given by the two methods. At Harvard College Observatory, the third method is employed in all differential observations.

Each method has its advantages, and also its disadvantages. In the use of the first method, either the latitude must be considered as known, or else it must enter as an unknown quantity into the equations of condition formed from the observations. Easy reference to a fixed point would seem to be about the only advantage that can be claimed for this method. Except for this there would seem to be no good reason why we should measure a quantity which is not the quantity sought. Polar distance is the co-ordinate to be directly measured, and the polar-point correction is the correction needed. This can be obtained by observing the polar distance of the Pole-star at both the upper and lower culminations. This method has been exclusively followed for the past five years in the series of observations undertaken by the writer, for the determination of the absolute co-ordinates of about one hundred stars between the first and fourth magnitudes. The defect of this method consists in the requirement that the index error of the circle must remain constant between two adjacent culminations.

It is proposed to verify the constancy of this quantity in the following way.

It has been found that the reversible level invented by Mr. John Clark of the United States Coast Survey serves in the most admirable way to define a fixed reference plane. The reading of the microscopes of the Harvard College Meridian Circle for the indicated zero of the level, which is attached to the cube of the telescope, has now been continued without interruption for nearly two years. A provisional discussion of the results shows that the reference plane thus indicated remains nearly invariable, — certainly it is more steady than the position of the mean of the microscopes upon the circular frame upon which they are mounted with respect to the position of the circle itself.

It is proposed to mount a level of this form upon a horizontal table attached to an arm having an angle with the axis of the earth nearly equal to the polar distance of Polaris when the telescope is set at this polar distance. If the lower end of this arm is mounted upon centres, and if there is attached to the upper end a micrometer screw which is tangent to the arc of revolution, it is obvious that, when the reading of the screw for either culmination of Polaris is known, we can measure the deviation of the optical axis of the telescope from this plane by reading the circle, the level, and the index of the micrometer screw. In this way a constant watch may be kept upon the position of the microscopes with respect to the circle. The whole apparatus may be conveniently attached to the cube of the telescope. The steadiness of both the level and the microscopes may be inferred from the following readings of the circle for the zero line of the level. They involve the accidental errors of reading both of the microscopes and of the level, as well as actual changes in the position of the mean of the four microscopes. That part of the change which is due to the latter cause will be determined when the observations of Polaris are reduced. Only the seconds of arc are given.

Date.	Circle Reading.	Date.	Circle Reading.	Date.	Circle Reading.
1883.		1883.		1883.	
Feb. 7	57″.3	March 7	57″.6	March 28	57″.3
11	58.8	8	55.7	28	57.5
13	59.8	11	57.4	29	58.5
18	58.7	12	56.5	29	59.8
19	58.3	13	57.5	30	59.3
23	54.9	15	57.6	April 1	60.3
23	56.4	15	59.4	2	56.6
25	55.9	21	57.9	3	57.0
27	58.6	22	57.4	6	57.4
March 2	56.8	24	59.2		
2	57.4	26	60.1		

XXII.

STUDIES IN METROLOGY.

FIRST PAPER.

BY WILLIAM A. ROGERS.

Presented May 9th, 1883.

IT will be the aim of the present paper to present a critical study of certain standards of length, which have been compared either directly or indirectly with the original standards, which are now recognized throughout the civilized world as the ultimate and supreme authority in all matters relating to units of length; viz. with the "Imperial Yard" at London, and with the "Metre des Archives" at the International Bureau of Weights and Measures, situated at Breteuil, near Paris.

The second paper will contain a discussion of all the standards of length which have been constructed by the writer from the prototypes investigated in this paper. These prototypes are designated and defined as follows:—

I. *The Tresca Meter, having the designation T.*

The bar upon which the defining lines of this meter are traced is composed of pure copper, and has narrow strips of platinum inserted at each end. The bar has the X shape proposed by Professor Tresca, which allows the graduations to be placed nearly in the plane of the neutral axis without interfering materially with their examination under a microscope having considerable magnifying power.

The platinum surfaces are in the same plane with the surface of the copper, not only at each end, but throughout the entire length. These surfaces are fairly well adapted to receive sharply defined graduations; but this material is far inferior to platinum-iridium in this respect.

This bar was placed upon the tracing comparator of the Conservatoire des Arts et Metiers, on the morning of February 4, 1880. After remaining at a constant temperature for about forty hours, M. Gustave

Tresca, at two o'clock on the morning of February 6, transferred to it the Conservatory line meter No. 19, whose relation to the Metre des Archives had been previously determined with great exactness by Professor Tresca. There are three defining lines at each end, with an interval of 17.4 μ. The width of each line is about 5 μ. It appears from a large number of subsequent comparisons of the three meters defined by these lines, that they do not differ *inter se* by a measurable quantity.

Immediately after the transfer was completed, a direct comparison with meter No. 19 was made. Comparisons were continued during the next day and the next night.

The certificate which accompanied this meter states that it is 1.00 μ longer than the corrected value of meter No. 19 at 13°.70 C.

Employing in the reduction the coefficient of expansion for No. 19, .00000860860, we find, therefore, that

T is 118.94 μ *too long at* 13°.70 C.

II. *The Froment Meter, designated F.*

This meter was originally an end measure only. The metal is steel, but the end surfaces were not hardened. This meter has been compared indirectly with the Metre des Archives through a comparison with a meter belonging to the Observatory of Kazan, which, by a comparison with the meter of the Conservatory, had been found to be 2.431 μ too long. During a visit to the establishment of Messrs. Demoulins-Froment, I ascertained that M. Froment had a line meter upon steel, which was supposed to be the equivalent of the end meter. Having purchased the latter, I asked M. Diner, who has this class of work in charge, to transfer to its upper surface this line meter, with subdivisions into decimeters. Inasmuch as the upper part of the bar extends beyond the defining surfaces of the meter at each end, this transfer was fortunately feasible. The transfer by M. Diner was made with great care, and from a comparison which I was permitted to make with the comparator of M. Froment, I became convinced that the claim of M. Diner, that the limit of error did not exceed 2 μ, was clearly substantiated.

The defining surfaces of the end meter are parallel only in the vertical plane, which is perpendicular to the axis of the bar. It will appear from the discussion which will follow, that, if the measurements are made from contacts on either side of the vertical line passing through the centre of the bar, an error will be introduced which is proportional in magnitude to the distance from this line. Its maximum value is about 8 μ.

In this discussion the end meter will be designated F_e, and the line meter F_l. We have, then,

$$F_e - 8.43\,\mu = \text{Metre des Archives.}$$
$$F_l = F_e \text{ nearly.}$$

Upon placing F_e upon my own comparator after my return to Cambridge, I was surprised to find that, when the terminal lines were in focus, the lines along the middle of the bar were barely visible under the microscope. I was the more surprised, as I had examined the bar with respect to this very point while at Paris. After becoming assured that the ways of my own comparator had no sensible flexure, by certain tests which will be described later in this paper, only one conclusion could be reached; viz. either that the microscopes employed in the examination at Paris had not sufficient power to enable the observer to detect the deviation of the ways of the comparator from a horizontal plane, or that the curvature of the ways was the same as the curvature of the bar.

Inasmuch as it was not possible on this account to determine exactly the relation of each decimeter of F_l to the entire meter, and because the softness of the metal prevented the repetition of exact end contacts, I decided to reconstruct this bar for my own use. Before this was done, however, the following operations were performed.

(*a.*) The terminal lines of F_l were transferred to T at 13°.70 C. nearly.

Two sets of graduations were made, one composed of five rather coarse lines, and the other composed of five lines having as nearly as possible the same characteristics as the Tresca defining lines. The former are designated $T^{b_1 \cdots 5}$, and the latter $T^{c_1 \cdots 5}$. Corresponding lines were traced at the middle point of T upon the surface of copper. At the same time, a provisional yard was laid off upon T, employing one defining line of the meter as the defining line of the yard at that end.

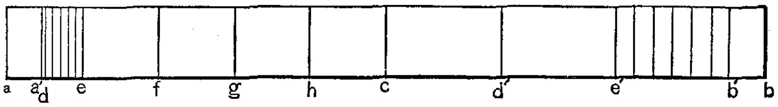
(*b.*) The relations between F_l and $T^{a_1 \cdots 3}$ and $T^{b_1 \cdots 5}$ were carefully determined.

(*c.*) The relation of F_e to $T^{a_1 \cdots 3}$, and also to three other meters to be described hereafter, was determined.

After this work was done, hardened steel plugs were inserted at the ends of F_e, and the surfaces were made parallel. In order to accomplish this, it was necessary to grind off a trifle more than the 8.4 μ, by which amount F_e was longer than the meter of the Archives. The amount by which the length was actually diminished will appear in the discussion which follows.

The upper surface of this bar was made nearly a plane surface when supported at its neutral points. The amount of metal removed at the middle point was about .012 inch. Tempered steel plugs were then inserted with a close fit in the upper surface of the bar, according to a scheme shown in the following sketch: —

DIAGRAM ILLUSTRATING SUBDIVISIONS OF THE YARD AND METER.



METRIC.

a b = 1 Meter.
a c = c b = ½ Meter.
a e = e f = f g = g h = h c = 1 Decimeter.
a d = d e = 5 Centimeters.
d e subdivided to Centimeters.

ENGLISH.

a' b' = 1 Yard.
a' c = c b' = ½ Yard.
c d' = d' e' = e' b' = 6 Inches.
e' b' subdivided to Inches.

By means of a device suggested by Mr. George F. Ballou, who prepared the bar, the surfaces of these plugs were brought into the same focal plane after they had received the final polish. At this point it will be proper to explain the method by which the general surface of graduated bars is made plane.

As will be hereafter shown, a plate to which a microscope is attached slides freely upon the ways of the comparator. The flexure of these ways is controlled by means of flexure screws beneath. It is evident that, if the objective of a microscope of high power remains in good focus at every point along a polished metal surface lying parallel with a plane passing through the points of contact at the two ends of the ways, the movement of the microscope plate along the ways defines a reference plane with which any other plane can be compared. The following tests have been employed in the definition of this reference plane.

(1.) Mr. George B. Clark, of the firm of Alvan Clark & Sons, prepared for me a steel bar, one meter in length, which has one optically plane surface, *when the bar is supported at its neutral points.* Placing the bar thus supported upon the comparator, and adjusting it so that surfaces at the two ends are in a focal plane parallel with that defined by the microscope plate in corresponding positions, it has been found that the objective remains in focus at every point along the surface of this bar.

(2.) A similar test has been applied with a surface plate 42 × 1½ × 6 inches, prepared by Professor Morris of Cornell University. I have two of these surface plates. One was prepared in the usual way, but the other was not touched with a tool after it left the planer. I think it would be difficult to find a better specimen of planing. Although each plate weighs about twenty-five pounds, one will lift the other by the contact of their surfaces.

(3.) If a shallow dish of mercury is placed upon the comparator, the surface of the mercury forms a reference plane with which the plane described by the microscope plate can be compared. Under a half-inch objective supplied with a Tolles opaque illuminator, one can focus upon the minute globules of mercury with considerable sharpness.

Having proved that the microscope plate describes a true plane during its movement along the ways, the bar whose surface is to be prepared is placed upon the comparator, *supported at its neutral points*, and the surface is worked down with soft stone till every part remains sharply in focus under the objective.

Experience has shown that the surface of every bar prepared in this way falls into a plane surface within a short time after it is placed upon its supports.

(4.) Recently a fourth method of testing the deviation of the plane described by the microscope carriage from a true horizontal plane has been applied with good success. It may be described as "the method by two microscopes." A flat bar, about sixty centimeters in length, was attached firmly to the carriage in a direction parallel with the ways. At each end, the arm which supports the microscope was fastened with an adjustable motion in every direction. The two microscopes when placed in position are one half-meter apart, and equidistant from the centre of the carriage.

The Clark reference bar having been placed in position upon the bed of the comparator, the defining lines of each end were adjusted for focus under the right-hand microscope. The flexure screws beneath the comparator were then moved till the defining line at the middle point was in sharp focus. It is now found that every part of the surface of the reference plate remains in good focus. But it does not follow that either the plane described by the microscope carriage or that of the reference bar are real planes. It can only be said that they are parallel. We now adjust the left-hand microscope upon the reference bar at the left end. Now, if the microscope carriage describes a true plane in passing from the middle point to the right end of the comparator, the defining line near the middle point of the bar at which the other microscope had been adjusted for focus *will remain in focus under the left-hand microscope.*

This operation will test the movement of the carriage over only one half of the distance moved, viz. from the middle to the right end. But by adjusting the left microscope upon the right end of the bar, and moving the carriage from right to left, the remaining half can be tested in a similar manner. It is found that only two or three trials need to be made in the adjustment of the bed-plate by means of the flexure screws in order that the defining lines at each end of the reference bar shall remain in sharp focus under both microscopes. Of course, the lines at the middle of the bar will now remain in focus only when they are in the same plane as the terminal lines. In the case of the Clark reference bar this condition is fulfilled with great exactness. It will be noticed that this method does not require that the surface of the reference bar shall be a true plane. Any two points may be chosen, but these points must remain in the same plane during the entire operation of testing.

Since this method has been adopted, much better results have been obtained than it was possible to obtain before.

(5.) A fifth method avoids dependence upon the variation of focus as the test of a plane surface. In this method the microscope is attached to the carriage in a horizontal position, the line of sight being a little above the surface of a bar which is supposed to be a plane surface, and with which the plane described by the microscope carriage is to be compared.

If a small piece of metal having one plane surface is placed at different positions upon the surface of the reference bar, a given point upon the front face, formed by the intersection of a perpendicular and a horizontal defining line, will remain in a plane parallel with the surface of the bar. This test-piece is first placed at one end, and the defining horizontal line is brought into coincidence with the defining line of the microscope micrometer. The carriage is then moved to the other end, and the test-piece is moved upon the surface of the bar till the cross lines are brought into the field of the microscope. The coincidence with the micrometer line is then made by the vertical adjustment of the bar. The test-piece is now placed at the centre of the reference bar, and, if the coincidence of the defining lines is still maintained, the surface described by the carriage is parallel with the surface of the bar. The deflection of the ways at any point can thus be measured by means of the micrometer screw of the microscope.

This method of preparing the surfaces of bars for graduation obviates the inconvenience of placing the defining lines at the bottom of wells in order to reach the plane passing through the neutral axis, and it enables one to place the terminal lines and the lines marking the subdivisions in the same plane.

The steel bar prepared in this way is designated R_1. Three sets of graduations are traced upon the polished surfaces of the steel plugs. They are designated as follows: —

$$R_1^{a_{12}}, \quad R_1^{b_{123}}, \quad R_1^{c_{12345}}.$$

Lines $R_1^{a_1}$ define the meter and the yard provisionally at 62°.0 Fahr. The corrections required for these defining lines having been ascertained from a sufficient number of observations, they were applied in tracing the remaining graduations. The lines of the group R_1^{c} vary in width between 0.6 μ and 5 μ. They are therefore well adapted to furnish the data required in order to determine the effect of the size of the lines upon the error of focus under the objective.

III. *The Bronze Yard and Meter, designated* R_2.

The material of this standard is an alloy known as Bailey's metal. It consists of 16 parts of copper, 2½ parts of tin, and 1 part of zinc. It is identical in composition with the Imperial Yard, and differs from it only in having the graduations upon platinum-iridium plugs, which have their polished surfaces in the plane of one surface of the bar when it is supported at its neutral points, instead of having them upon plugs of gold situated at the bottom of wells sunk to the plane of the neutral axis.

This standard forms the basis of the units which the writer undertook to obtain for Messrs. Pratt and Whitney, of Hartford, Connecticut, and upon which their system of gauges depends.

Both the yard and the meter are nearly standard at 62° Fahr. The defining lines of the meter were obtained by transfer from the Tresca meter. The defining lines of the yard were obtained indirectly from the Imperial Yard, in the following manner.

Early in 1880, Mr. Chaney, Warden of the Standards, did me the great service to compare a yard traced upon the surface of a steel bar with the Imperial Yard. According to the observations of Mr. Chaney, the yard traced upon this bar was .000316 of an inch too short at 62° Fahr. Unfortunately, this bar had been nickel-plated, and the graduations were traced upon the nickel surface. Subsequent investigations revealed the fact that the expansion and contraction of this bar were very irregular, and that the normal action under a given change of temperature could be obtained only by maintaining a constant temperature for about twelve hours. Fortunately, a portion of the comparisons with the Imperial Yard were made under the required conditions, at the nearly constant temperature of 57° Fahr. When it became apparent that the transfer at 62° Fahr. from the steel bar to a bronze bar identical in form and construction with R_2 could not be made with the required exactness, it was decided to make the required transfers under conditions as nearly as possible the same as those under which the comparisons had been made at London. After maintaining the nearly constant temperature of 57° for about twenty-four hours, this transfer was made to a bronze bar designated R_0. After applying the reduction from 57° to 62°, Professor J. E. Hilgard, now Superintendent of the U. S. Coast Survey, having kindly offered to compare this yard with the standard yard known as "Bronze 11," which bears a known relation to the Imperial Yard, bar R_0 was sent to Washington for this comparison. According to the report of Professor Hilgard, this yard was found to be 24 millionths of an inch longer than "Bronze 11," or 64 millionths of an inch shorter than the Imperial Yard, adopting the relation

$$\text{"Bronze 11"} + .000088 \text{ in.} = \text{Imperial Yard.}$$

It was now possible to make the transfer from R_0 to R_2 with but little regard to the question of temperature, and with a known relation to the Imperial Yard. This transfer was made, January 13, 1881. The yard R_2 is subdivided into feet, and the first foot is further subdivided into inches. At one end a single line defines the limit of both the yard and the meter. The other defining line of the meter extends beyond the corresponding defining line of the yard 3.37 inches. For convenience in measuring this space, the yard is extended to 39 inches, with inch subdivisions. Subsequently the system of graduations upon R_1 were transferred to the brass surface of this bar, being traced near the edge. This set of graduations is designated R_{2e}.

IV. *The Brass Yard and Meter designated C. S.*

This standard was prepared by the U. S. Coast Survey many years ago, and presented to the Stevens Institute at Hoboken, N. J. By the kindness of President Morton I was permitted, in January, 1880, to take this standard to London in order to obtain a comparison of the yard with the Imperial Yard. This comparison was made with great care by Mr. Chaney, and, at his request, by the writer also. It was then sent to Breteuil for comparison of the meter with the International Meter. The bar was received from Paris, February 4, 1883. According to the report of Dr. Pernet, this meter is 310 μ *shorter than the Metre des Archives at* 0° C. Inasmuch as the comparisons with the prototype were made near 1°, 7°, and 12° Centigrade, with the greatest exactness, the data are at hand for the determination of the length of this metre at 16°.67 C., or 62° Fahr., but they have not yet been received. It is, however, quite as well that the present investigation should have been made independently, and without any knowledge of the results obtained at Breteuil.

The graduations are traced upon plugs of silver inserted at the bottom of wells sunk to the line of the neutral axis. The defining lines of the meter present sharply defined edges, but one of the defining lines of the yard has a somewhat broken appearance, being broader at some points than at others. Two lines about 3 mm. apart are drawn at right angles to the defining lines. It appears, from repeated examinations, that the defining lines, both for the meter and the yard, are sensibly parallel. The comparisons made by the writer have been made at points about midway between the horizontal lines.

V. *The Glass Yards and Meters designated G_1 and G_2.*

These bars were made by Chance and Sons in 1870, for the Standards Department, London. G_1 was presented to the writer by Mr. Chaney, under the authority of the Board of Trade, in 1880. G_2 is the property of the Standards Department. It was intrusted to the writer for the purpose of graduation.

If one may judge from the character of the lines ruled with the diamond, these bars are far from homogeneous throughout their whole extent. With the same pressure upon the diamond, some of the lines are slightly broader than others, and while nearly all of the lines are of good quality, a few of them present a decided granular structure.

In the transfer of the graduations from one standard to another having a different composition, I have found it advisable to first make a provisional transfer, with an assumed relative coefficient of expansion between the two bars, and with an assumed series of corrections to the prototype on account of the horizontal curvature of the ways.

The bars are then placed upon the universal comparator, and the relations between the prototype and the standard constructed from it are determined by a sufficient number of observations, at a wide range of temperature. This operation generally requires two or three weeks. With the corrections thus determined, a second series of graduations are laid off, the lines being in the same field of the microscope as the first ones. One can now proceed nearly independently of temperature, by comparison with the first set of graduations.

Even when the correct length is obtained, it is often found necessary to make a third, and even a fourth set, in order to reduce the errors of the subdivisions to sufficiently narrow limits. According to my present arrangement, after a transfer has been made, all the subdivisions, both of the meter and the yard, can be made without disturbing the position of the two bars. But with the utmost care I have not found it possible to make the subdivisions exactly equal. In fact, one must be content to admit errors of small magnitude as long as the conditions of transfer vary in the slightest degree from the conditions under which the required corrections were obtained. The corrections due to curvature give great trouble, and require the most careful determination. With the universal comparator, this difficulty is obviated; but on account of the better illumination obtained in the comparing-room at the Observatory, all transfers have thus far been made upon the comparator first constructed.

The provisional set of graduations upon G_1 and G_2 were laid off from $R_1^{a_2}$, on January 7, 1883. They consist of bands of three lines, separated by an interval of 50 μ. They are designated $G_1^{a_{123}}$ and $G_2^{a_{123}}$.

The relations between R_1, G_1, and G_2 were then determined from observations extending from January 8 to January 17.

In July of the present year, G_1 and G_2 were placed upon the comparator for the transfer of the graduations $G_2^{a_2}$ to G_1, giving a set of graduations designated $G_1^{b_{12345}}$. After the comparison of the latter with $G_1^{a_2}$, and with the series of corrections thus obtained, the bars were placed in reversed positions, and lines $G_1^{b_1}$ were made the basis of a new transfer to G_2, giving $G_2^{b_{123}}$.

Graduations $G_2^{b_2}$ having been compared with each other and with $G_2^{a_2}$, the following sets were laid off, viz.: —

$G_2^{c_{123}}$ with lines one half the width of $G_2^{b_{123}}$.

$G_2^{d_2}$ with lines having about the same width as $G_2^{b_{123}}$.

$G_2^{e_2}$ with exceedingly fine lines.

The distance between the lines in the final sets both of G_1 and G_2 is 50 μ.

VI. *The Whitworth Steel Yard, designated W.*

This yard is an end-measure standard. It was purchased of Sir Joseph Whitworth & Co., in 1880, at the cost of about $70. No statement of the correction required for the length of the yard at 62° accompanied it. One may infer, therefore, that it was considered standard at that temperature. The terminal surfaces which define the yard are one half-inch in diameter. All the observations which have been made indicate that these surfaces are exactly parallel. The steel has been tempered at each end, the temper extending about one inch.

This bar has been included in the present list of prototypes on account of the relation which it may be supposed to bear to the system of gauges universally adopted in Great Britain. The original from which the Whitworth steel standards were constructed seems to have been a bronze bar made by Troughton and Sims at the same time the national standards were made by these distinguished mechanicians. It does not appear that this yard was included among those compared by Sheepshanks. Probably, however, its relation to them was determined by Mr. Sims. I have been unable to find any record of a direct comparison with the Imperial Yard, but without question the correspondence must be very close. The transfer of this yard to steel involves many considerations which do not enter into a comparison of standards having the same composition as the Imperial Yard. The great service which Whitworth has rendered to the science of metrology would lead us to expect that the steel yard which is the result of his researches truly represents the bronze yard when converted into its equivalent upon steel at 62°. Nor is this expectation disappointed. A certain allowance must always be made for the different conditions under which independent investigations are made. It will not do to say that the error is all on one side. But admitting that the Whitworth steel standard really differs from the steel standard yard R_1 by the amount indicated by this discussion, it yet remains true that this difference will disappear from the exact subdivisions of the yard with the units which are required in exact mechanical operations, viz. the inch and its multiples.

The important data with respect to the prototypes described above are presented in the following table.

DIMENSIONS.

Bar.	Weight.	Length.	Width.	Depth.
T	3.1 lb.	101 cm.	2.0 cm.	2.0 cm.
$C. S.$	7.1 "	102 "	2.5 "	1.4 "
$R_1 = F$	7.6 "	101 "	1.4 "	3.0 "
R_2	12.8 "	102 "	2.5 "	2.5 "
G_1	12.5 "	102 "	4.0 "	4.0 "
G_2	12.5 "	102 "	4.0 "	4.0 "
W	9.3 "	91 "	2.5 "	2.5 "

WIDTH OF DEFINING LINES.

$T^{a_{123}} = 5\,\mu$

$T^{b_{1\cdots5}} = 7\,\mu$

$T^{c_{1\cdots3}} = 4\,\mu$

$C.S.$, meter $= 18\,\mu$

$C.S.$, yard $= 7\,\mu$

$C.S.$, max. $= 10\,\mu$

$C.S.$, min. $= 6\,\mu$

$R_2^{a_{123}} = 5\,\mu$

$G_1^{a_{123}} = 5.0\,\mu$

$G_1^{b_{1\cdots5}} = 3.0\,\mu$

$G_2^{a_{123}} = 4.0\,\mu$

$G_2^{b_{123}} = 3.0\,\mu$

$G_2^{c_{123}} = 1.5\,\mu$

$G_2^{d_{123}} = 3.0\,\mu$

$G_2^{e_{123}} = 0.5\,\mu$

$R_1^{a_1} = 7.0\,\mu$

$R_1^{a_2} = 4.0\,\mu$

$R_1^{b_{123}} = 3.1\,\mu$

$R_1^{c_1} = 0.6\,\mu$

$R_1^{c_2} = 1.2\,\mu$

$R_1^{c_3} = 2.0\,\mu$

$R_1^{c_4} = 7.7\,\mu$

$R_1^{c_5} = 3.4\,\mu$

The discussion of these prototypes will proceed in the following order: —

(*a*) Description of comparators.
(*b*) Description of comparing-rooms.
(*c*) Discussion of thermometers.
(*d*) Description of microscopes. Values of the micrometer screws.
(*e*) Investigation of the time required for a given change of temperature to produce its normal effect upon bars having different masses.

(*f*) 1. Report of Professor Hilgard upon the comparison of $R_2^{a_2}$ with "Bronze 11," made by Assistant Edwin Smith.

2. Comparison of $R_2^{a_2}$ with "Bronze 11," at Washington, with Comparator No. 1.

3. Comparison of T^{a_2} with Meter "No. 49," at Washington.

(*g*) Preliminary comparisons of standards at Cambridge with Comparator No. 1, and with the Universal Comparator.

(*h*) Investigation of coefficients of expansion.

(*i*) Final comparisons of prototype standards.

(*j*) Probable error of observations.

(*k*) Tabular values of errors of subdivision.

(*l*) Investigation of the equation between the Imperial Yard and the Metre des Archives.

COMPARATOR No. 1.

This comparator is of the most simple form. It consists of a bed-plate 60 inches in length, 14 inches in breadth, and is ribbed to the depth of 2½ inches. V-shaped ways extend the entire length. A carriage 8 × 6 inches is carried along these ways, either by hand movement or by a rack and free pinion. The rack, which is placed midway between the ways, extends the whole length of the bed-plate, and the shaft which carries the pinion is placed at the centre of the carriage. On each side of the centre, two independent platforms are mounted with vertical adjustments, to which the microscopes are attached. There is, besides, sufficient room at one end of the carriage for the tracing apparatus, which may thus be made to maintain a fixed relation to either microscope.

Gibbed grooves extend the whole length of the bed-plate, to which are fitted two stop-plates, 4 × 5 inches, which can be clamped firmly to the bed at any point. Oval-shaped tempered steel stops are inserted in the end foces of these plates, and corresponding flat surfaces of steel are inserted at each end of the microscope carriage.

The flexure of the bed-plate is taken up by means of two screws, which are attached to an independent plate beneath and near the middle point.

The V-shaped ways have a decided horizontal curvature, which gave great trouble until the form of the curve had been investigated. Several independent investigations of the effect of this curvature have been made, both for the yard and the meter, with the following results.

	For one-inch objective.	
	Correction to be applied to a measured yard for each inch of distance from the centre of the ways.	Correction to be applied to a measured meter for each centimeter of distance from the centre of the ways.
Mean of values derived from observations previous to Jan. 1, 1881	div. 10.50	div. 4.74
Values obtained at Washington .	10.43	4.57
Values derived from equations of condition subsequent to 1881. .	10.46	4.58
Values derived from direct measures subsequent to 1881 . . .	10.43	4.26
	10.45	4.54

The general principle of this form of construction, and the methods of comparison employed, will more clearly appear from the drawings and description of the Universal Comparator which follow.

The Rogers–Bond Universal Comparator.

This comparator is the outgrowth of experience with the apparatus first constructed. In 1880, through the kind offices of Professor J. E. Denton, of Stevens Institute, Mr. George M. Bond, then a member of the Senior Class, came to Cambridge and made the sketches, from which he afterwards executed the full drawings. Mr. Bond was intrusted with the entire arrangement of all details, and to his judicious application of sound mechanical principles in the form of construction is due in a large measure the successful working of the apparatus.

Soon after this, Messrs. Pratt and Whitney, of Hartford, Conn., undertook the construction of two machines from these specifications, one of which was to be used as an auxiliary in the investigation and construction of the system of gauges which they have established. These comparators were completed in May, 1881; but it was not until the September following that the machine constructed for the writer was completely mounted at Cambridge.

In designing this apparatus, the following requirements were kept steadily in view: —

(1.) The complete separation of the standards to be compared from the frame-work to which the microscopes are attached.

(2.) The best method of securing an invariable reference plane, defined by the motion of the microscope along the ways upon which it rests.

(3.) Mechanism for the adjustment of the bars under the microscopes in the shortest possible time, by a combined quick and slow motion, which should not require any disturbance of the standards after they are placed in position upon their neutral points of support. The three quick and slow movements required are:

(*a*.) A motion of translation, longitudinally.
(*b*.) A motion at right angles to the motion of translation.
(*c*.) A vertical motion.

(4.) Mechanism which will allow comparisons of line-measures by as many independent methods as possible.

(5.) Mechanism for the convenient comparison of line-measures with end-measures.

(6.) Mechanism which will allow an easy comparison of the subdivisions of any unit, without regard to their magnitude.

Figures 2 and 3 present perspective views of the apparatus, and show the general relations of all the parts to each other. The plan of the comparator is shown in Fig. 4. The front elevation is shown in Fig. 1, in which the part above the line A B is lifted, in order that it may be seen clear of the tables. The form of the micrometer of the microscope is shown in Fig. 6. The general form of the microscope carriage, with microscope in position, is shown in Fig. 7. An end view of the carriage G is shown in Fig. 5.

The first condition named is fulfilled by mounting the bed-plate L L, Fig. 1, upon brick piers having granite cap-stones. The bed-plate of the carriage G, which supports the tables S, rests upon independent piers. Both of these sets of piers are disconnected from the floor of the comparing-room.

The second condition is fulfilled by the use of the hollow steel cylinders X. The microscope plate, K, moves freely upon these cylindrical ways. It can also be moved by a rack and free pinion. The rack is behind the cylinder X, but the head, R, of the pinion is shown. The flexure of the cylinders is taken up by the levers P, T, which are not shown in their proper position. They should be nearer the centre. The required pressure is supplied by weights attached to cords fastened to the ends of the lever P.

It is due to the excellent workmanship of the Pratt and Whitney Company that these ways have no appreciable horizontal curvature, while the very slight deflection due to flexure is readily taken up by the flexure levers. An experience of nearly two years has shown that the reference plane described by the movement of the microscope carriage is nearly invariable.

The third requirement is met by the following arrangement.

The standards to be compared are placed upon the table S^2, Fig. 1. The whole framework to which this table is attached can be raised or lowered by the hand-wheel C. It can also be moved forward and backward, upon the ways shown in Figs. 3 and 4, by means of bevelled gears driven by the hand-wheels beneath the bed-plate. These coarse movements are designed to facilitate placing the standards to be measured approximately in the proper position in relation to the microscopes M, M^1.

The carriage S is moved rapidly upon the V-shaped ways at the upper surface of E, by a rack and free pinion movement. The rack is shown at the left of the figure, while the handle of the pinion is shown at D.

The standards having been placed in such a position upon the table S that the defining lines at one end shall be nearly over the fulcrum below S^3, the coarse motion in a direction at right angles to the motion of the carriage S is obtained by the gibbed slides, S^3.

The slow movement of the carriage is obtained as follows: —

(1.) In translation, by the lever whose handle is shown at S^5.
(2.) At right angles to the motion of translation, by the lever S^6.
(3.) Vertically, by means of the screw S^3 shown in the left-hand carriage.

In practice it is found that these levers give a more delicate adjustment than can be obtained with a screw movement, and quite as good as can be obtained with the micrometer screw of the microscope. It will be observed that the position of the standards with reference to the table S is not disturbed by any of these adjustments. The time required in order to bring the terminal lines of a yard or meter into proper position, adjustment, and focus under the microscopes, is about forty seconds.

Under the fourth requirement the following methods of comparison are described.

(*a.*) *Comparison by means of two Fixed Microscopes.*

The method of procedure will be illustrated by a description in detail of the comparison of the standards of which the results are given on the following pages. The following are the various steps of the operation: —

THE ROGERS-BOND COMPARATOR.

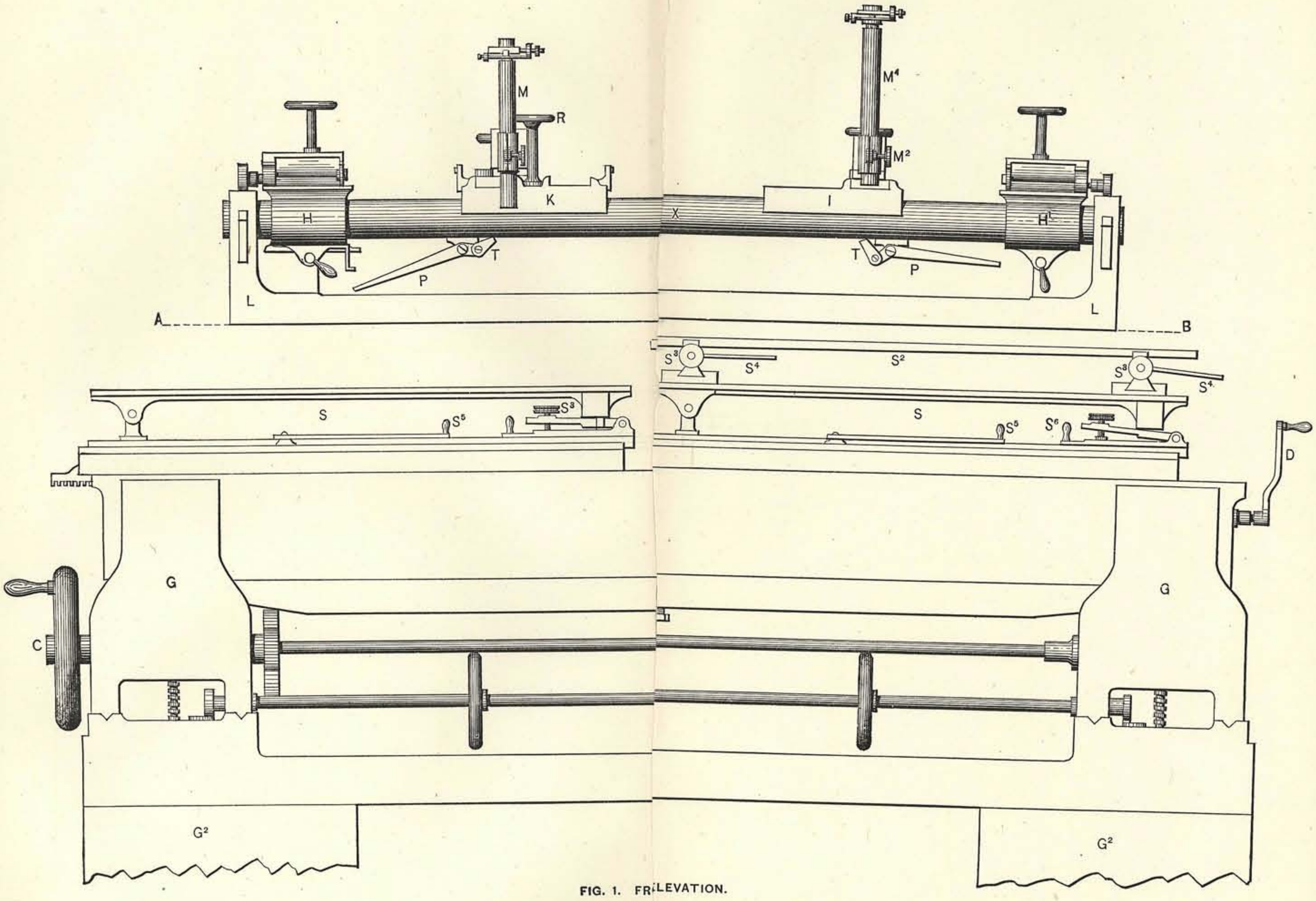

M
R
K
X
I
M^4
M^2
H
H^1
T
P
T
P
L
L
A
B
S^3
S^4
S^2
S^3
S^4
S
S^5
S^3
S
S^5
S^6
D
G
G
C
G^2
G^2

FIG. 1. FR ELEVATION.

Part above line A B *o show clear of tables.*

THE ROGERS-BOND COMPARATOR.

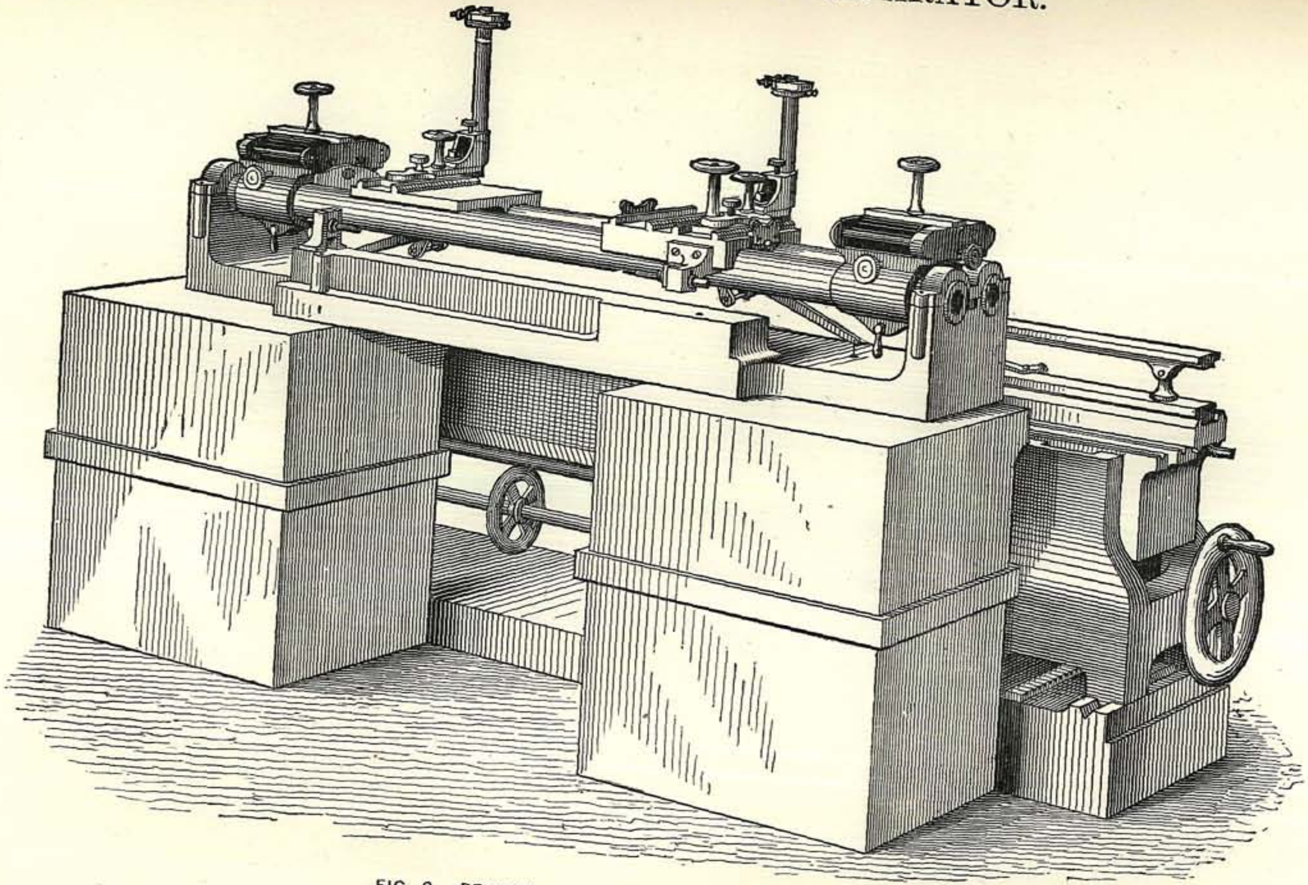


FIG. 2. FRONT VIEW, TABLES FOR STANDARDS, ETC.

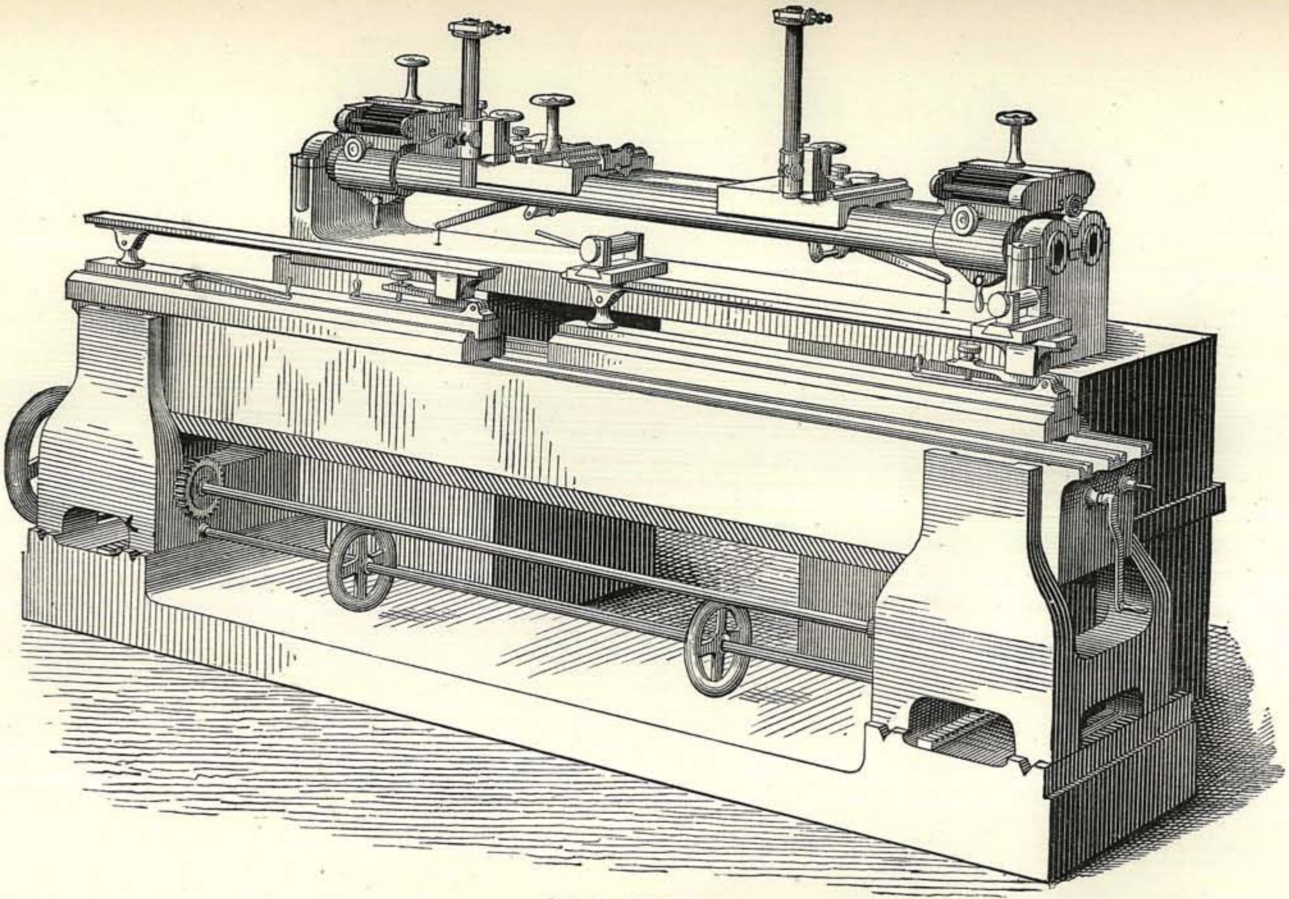


FIG. 3. REAR VIEW.

THE ROGERS-BOND COMPARATOR.

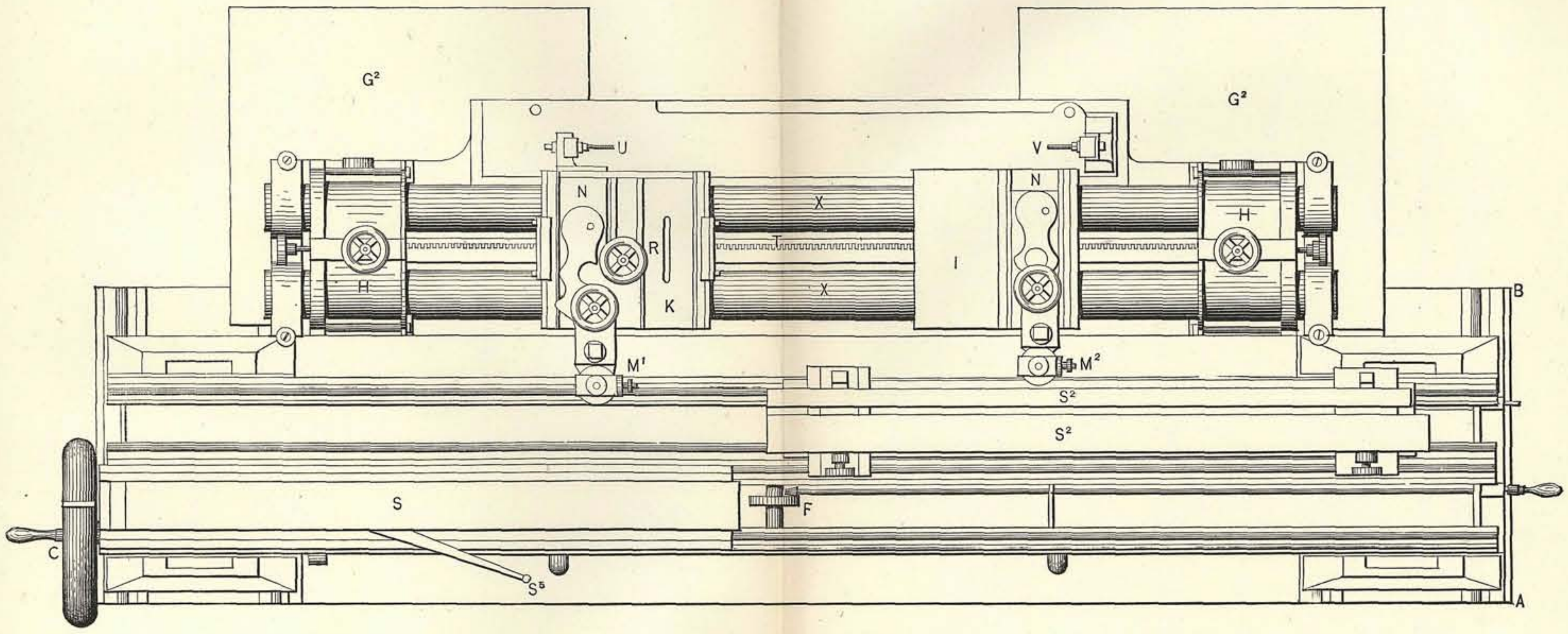

G^2
G^2
U
V
N
N
X
T
X
H
H
R
K
I
B
M^1
M^2
S^2
S^2
S
F
C
S^5
A

FIG. 4. PLAN OF COMPARATOR.

THE ROGERS-BOND COMPARATOR.

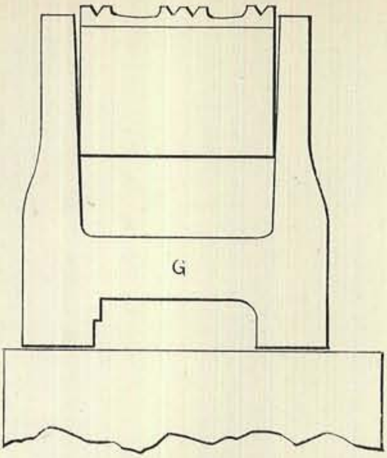


FIG. 5. END OF CARRIAGE G IN FIG. 1.

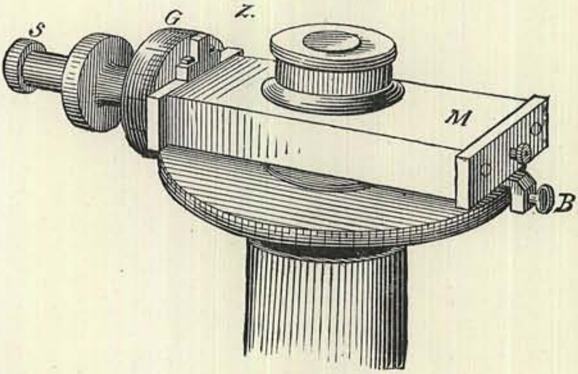


FIG. 6. THE MICROMETER.

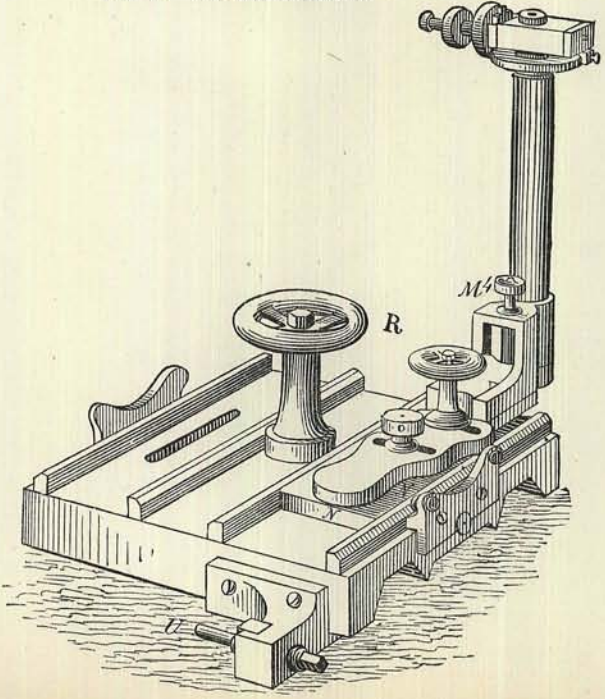


FIG. 7. THE MICROSCOPE CARRIAGE.

(1.) Adjustment of the standards T, $C.\ S.$, R_1, and R_2, upon supports at their neutral points, upon the table S^2. The defining lines at one end were placed nearly over the fulcrum at the left end of the carriage. T, having the least mass, is placed in front.

(2.) Permanent adjustment of the microscope plate I at a convenient distance from the end of the frame L.

(3.) Rapid movement of the carriage S by the handle D, until the right defining line of the meter T is brought nearly under the microscope M^1.

(4.) Movement of the plate K by the hand-wheel R, until the defining lines at the opposite end of T are brought into the field of the microscope M.

(5.) Adjustment of the left-hand defining line under the micrometer of the microscope M, by the horizontal movement of the slide S^3, and by the vertical movement S^4, and finally by the movement of translation through the lever S^5. The first two of these movements are made with sufficient exactness by the coarse adjustment. The defining line of the standard having been brought into coincidence with the fixed line of the micrometer of M by the fine adjustment S^5, no further change is made in the positions of K and I.

(6.) The adjustment of the right defining line by the motion of the micrometer of M^1, by the lever S^6, and by the vertical screw S^3. These adjustments will disturb the adjustment under M only in a slight degree. Usually, however, a second series of adjustments is necessary.

(7). The length of T having thus been transferred to the microscopes M, M^1, the standard $C.\ S.$ is then brought into position by the slides S^3, and the adjustments described above are repeated. The left defining line being coincident with the fixed wire of M, the difference in the length of the two standards is measured by means of the micrometer of M^1. An increasing reading of the micrometer-head corresponds to an increase of length.

(8.) Comparison of the meters R_1 and R_2 in a similar manner.

(9.) Adjustment of the defining line of the yard of $C.\ S.$ under M^1, by a rapid movement of the carriage S through the hand-lever D.

(10.) Movement of the plate K till the left defining line of the yard falls under the microscope M.

(11.) Repetition of the various adjustments and measures described above.

The average time required to make these adjustments, and to take four readings of M^1 for the defining lines T^{a_2}, T^{b_1}, for each edge of

C. S., for $R_1^{a_2}$, $R_1^{b_2}$, and $R_2^{a_2}$ of the meter, and the corresponding defining lines of the yard, is nineteen minutes. The average time of a single comparison of two units is therefore somewhat less than two minutes.

(*b.*) *Comparison by means of two Microscopes attached to the same Movable Carriage.*

The steps are as follows: —

(1.) The standards are placed in position upon the table S, one near the middle, and the other at a given distance in front of it.

(2.) The microscope K occupying a position near the middle of the comparator, the defining line at the left end of the bar is brought into focus of the microscope M by the screw M^4, Fig. 7. The carriage is then moved by the handle D till the defining line at the right end of either one of the standards is in the field of the same microscope. The adjustment for parallelism with the cylindrical ways is now made with the lever S^6 and for focus with the screw S^3.

(3.) Both microscopes are now placed upon the plate K. By means of the adjustments shown in Fig. 7, microscope M is adjusted upon the left-hand defining line of one bar, and M^1 is adjusted upon the corresponding defining line of the bar in front of it.

(4.) By a motion in translation through D, the right defining line of the first bar is brought into the field of M, and adjusted for coincidence with the fixed micrometer wire by the lever S^5.

(5.) The difference in the length of the bars is then measured with the micrometer of M_1.

(6.) The bar in front is now placed at an equal distance back of the first bar, and the operation described above is repeated.

(7.) The mean of the two results will be the difference in the length of the standards, free from the effect of the curvature of the ways along which the carriage moves. The same result will be obtained if the microscope carriage is moved along the cylindrical ways, the bars remaining stationary during each independent operation; but the curvature eliminated will in this case be that which belongs to the cylindrical ways.

(*c.*) *Comparison by means of Stops and one Microscope.*

The stops H H^1 move freely upon the cylinders X X, but they are capable of being clamped to them with great firmness by the levers shown near L. At one end they terminate in an oval projection of tempered steel, which is hidden behind the cylinder X, in Fig. 1.

It is nearly in line with the centre of gravity of K, which has a corresponding flat surface of tempered steel at each end.

These stops receive a slow motion by means of a screw, which is shown near the pillow blocks in Fig. 3.

(1.) The stops H H^1 are set approximately, e. g. 1 meter apart plus the length of K, and are securely clamped.

(2.) The plate K is brought into contact with the left-hand stop.

(3.) The standard to be compared is placed upon S, and the carriage is moved by the arm D till the left-hand defining line is adjusted under M.

(4.) The plate K is then brought into contact with the right-hand stop, and the other defining line is brought into position and into focus under M by the adjustments already described.

(5.) These adjustments having been completed, K is brought into contact, first with H, and then with H^1, and the micrometer is read for each contact.

(6.) These operations are repeated for each standard compared. Since each one has been compared with the invariable distance between the stops, the data are thereby furnished for the comparison with each other. In practice, the standard with which other standards are to be compared is always compared first with the distance between the stops, the record being written at the left of the page. The following example will illustrate the form of record. *R* signifies contact with the right stop, and *L* with the left stop.

Bar *T.*				Bar *C. S.*				$(R'-L')-(R-L)$
L		R	$R-L$	L'		R'	$R'-L'$	
rev. 4	div. 16.2	div. 14.6	div. —1.6	rev. 4	div. 19.7	div. 19.9	div. +0.2	div. +1.8

Under these definitions, the second standard is longer than the first, when $(R' - L') - (R - L)$ is *positive*. In this case, therefore, *C. S.* is 1.8 div. longer than *T.*

With the microscope of Comparator No. 1, however, this order is reversed. In that case, the second standard is shorter than the first, when $(R' - L') - (R - L)$ is *positive*.

(*d.*) *Comparison by means of Stops, and with two Microscopes.*

(1.) The standards to be compared are placed side by side upon the table S, and the carriage is placed at a convenient point upon E.

(2.) The plates K and I are adjusted so that the defining lines of the first standard to be compared shall fall under the microscopes M and M^1.

(3.) The stops H and H^1, having been brought into contact with the plates K and I, are securely clamped.

(4.) After the adjustments for position and for focus have been made, successive contacts of the plates K and I are made with the stops H and H^1, and the microscopes M and M^1 are read for each contact. These operations having been repeated for each standard to be compared, the values of $(M^1 - M)$ when reduced to a common unit and compared *inter se*, will give the relations required.

It is the experience of the writer that the microscope carriage can be brought into actual contact with the stops, by means of the rack and pinion movement, with greater certainty than it is possible to make a coincidence of the micrometer thread with the defining lines of the standard. The following test has been frequently tried, and always with the most conclusive results. With a quarter-inch objective, in which the value of one division of the micrometer screw is only $0.11\ \mu$, a series of one hundred successive contacts with the stops were made without disturbing the position of the micrometer thread. The number of cases in which the deviation from the mean of the first two or three readings of the micrometer was perceptible to the eye were noted, and the amount of the deviation was estimated in terms of the apparent width of the micrometer thread. One hundred readings of the micrometer thread were then taken for coincidence with the defining line of the standard, the plate K remaining stationary. A comparison of the results obtained in this way has always been found to be in favor of the stop contacts. With a little experience on the part of the observer, the stop method admits of the highest degree of precision. It is the experience of the writer, that one hundred successive contacts may be made, in which another observer at the microscope will be unable to detect the slightest deviation from constancy.

The stop method, also, has the great advantage over all other methods, that it allows perfect freedom in the adjustment of the microscope for focus, at any time during the comparisons. It is only required that the stops shall remain fixed during the two or more comparisons.

But in order to meet the objection which is sometimes urged against the certainty of actual contact, an electro-magnetic attachment has been added to the stops H and H^1, by which the plates K and I are securely locked *after* the contact has been made by the rack and pinion movement. By means of a screw, shown at the left of H, the core of the magnet is adjusted at the proper distance with respect to the armature shown at the left of K, after contact has been made between the stops. A battery is employed of sufficient force to move the carriage K, when the magnet is one eighth inch distant from the armature.

(*e.*) *Comparison by means of two Microscopes placed in a Horizontal Position.*

(1.) By means of two angle-plates, microscopes M and M^1 are made to occupy a position at right angles to the position shown in Fig. 1.

(2.) The standards to be compared are placed upon the table S, supported at their neutral points, and with their graduated surfaces in a vertical plane.

(3.) The comparisons are then made in the manner described under (*a*).

By this arrangement, the apparatus becomes a vertical comparator. The intersection of the transverse line with the defining lines being in the plane of the neutral axis, the deflection will be inappreciable, even if the bar is not supported at its neutral points. The first suggestion of this form of apparatus is generally credited to Neuman, and the first construction to Wilde, who has given a full description of the vertical comparator, constructed under his supervision, in the Repertorium für Experimental-Physik, Vol. XIII. p. 567. But a comparator of this form, invented by Lane, had been in use for several years previous to this time in the office of the U. S. Coast Survey at Washington.

Under the fifth requirement the following methods are employed. The frame of the stop V, Fig. 4, is securely fastened to the bed-plate of the comparator. It has a vertical adjustment by means of gibbed ways. The stop U is firmly attached to the plate K. This stop has a vertical adjustment also; but the line V U was made parallel with the cylindrical ways by the makers.

For observations of this class, the plate N, Fig. 4, which carries the microscope M^1, occupies a position the reverse of that shown in the cut.

The line bar to be compared is first placed upon the table at a known distance outside of the line U V. The adjustments are then made as follows: —

(1.) The stops U V are set at the same height above the table.

(2.) The line bar is then adjusted so that the horizontal line is parallel with the cylindrical ways, and is at the same time in the focal plane of the objective. The means of adjustment in three planes are not shown in the figure, but they are the same as those already described. The frame which carries the lever movements is fitted to the bed-plate by the dowel pins O O.

(3.) The plate K is moved upon the cylindrical ways till a contact between U and V takes place. While the plate remains in this position, micrometer M^2 is read for coincidence with the defining line at this end of the bar.

(4.) The carriage having been moved to the other end, the end-measure standard is placed in position between the stops U and V.

(5.) After firm contacts have been made between the stops and the defining surfaces of the end-measure standard, through the hand-wheel R of the rack and pinion, microscope M^1 is read for coincidence with the defining line at that end of the bar. The difference in the two readings will be the difference in the length of the two standards, provided the cylinders have no horizontal curvature.

(6.) In order to eliminate the effect of horizontal curvature, the comparison is again made with the line bar, placed at the same distance inside of the line U V.

Good results have been obtained by this method, but it is of course open to two objections; first, that since the bar must be moved in order to secure contact at V, the pressure at the two ends is unequal; and second, that the force required to make the contacts secure, may produce indentations in the defining surfaces of the standard bar. It will be seen from the series of observations with the end-measure standard in melting ice, detailed on pp. 345–359, that the second objection will not hold if the steel is properly tempered. The difficulty, if it exists, is easily remedied by the use of protecting pieces having parallel surfaces. The first objection is a more serious one. It is certainly open to criticism in a theoretical view, but the results shown on page 350 seem to indicate that this objection is not a serious one in actual practice.

A second method of comparing line with end measures will need to be described without the aid of a drawing. The apparatus is attached to table S, Fig. 1.

Three requirements must be met in the successful comparison of line-measure with end-measure standards: —

(1.) The position of the end-measure standard must not be disturbed during the comparison.

(2.) If only one microscope is used, either the movement of the microscope along the horizontal defining line must be in the line of the stops, or there must be a convenient way of placing the line standard at an equal and constant distance on either side of the line of the stops, without the necessity of adjustment for parallelism and for focus. If two microscopes are used, means of adjustment in three planes become necessary.

(3.) The pressure of the stops at each end must be equal and constant.

These three conditions are met in the following arrangement. Upon a table attached to S, Fig. 1, two slides move freely upon cylindrical ways of rather small diameter, but they can be firmly secured to the cylinder at any point by clamps. A second slide is mounted upon each of these plates, which has a movement of about four inches upon a cylinder and a flat way. The parallelism of these upper plates with the plane described by the carriage K, is secured by an adjustable vertical piece which passes through the plate near one edge and rests upon the plane way, which has also a vertical adjustment. There are two of these plane ways, placed equidistant from the cylindrical way on either side. The carriage can therefore be reversed by simply lifting it from its semicircular bearings. These upper slides terminate with tempered steel stops, which were set by the maker in a line with each other, and in the vertical plane which passes through the axis of the cylinder. The forward motion is given by means of an adjustable spiral spring, while a lever and stop control the backward motion.

An adjustable graduated bar is firmly attached to each of these plates, which has its upper surface nearly in a line with the stops.

With this arrangement of stops it is possible to compare line with end measures by the aid of either one, two, or three microscopes. The method by two microscopes has decided advantages over any other tried by the writer. The explanation, therefore, will be limited to this method.

(1.) The two double-slide plates are placed in such a position upon the main cylindrical ways that the distance between the spring-stops is e. g. about one meter.

(2.) The end meter, supported at its neutral points, is placed between the stops, and an equal pressure upon each end is given by means of the adjustable springs.

(3.) Plate K is then placed nearly opposite one end of the meter, and plate I nearly opposite the other end.

The micrometer line of M^1 must now be placed exactly in the vertical plane with the contacts of the stops at one end, and the micrometer line of M must be placed in the same vertical plane with the contacts of the stops at the other end. This is accomplished in the following manner. The stop-plate is thrown back by means of the controlling lever, and a rectangular block of metal is placed between the stop and the defining surface of the bar. This block has two of its faces exactly parallel and one inch apart. The upper surface is supposed to be in the same plane as the upper surface of the short graduated reference-bar attached to the stop-plates. The upper surface has a slight projection at each end, which allows defining lines one inch apart. This surface is bisected approximately by a horizontal and a perpendicular defining line, and a perpendicular line is drawn at each end exactly half an inch from the line at the middle point.

The first step is to set the micrometer M^1 for coincidence at the intersection of the cross lines upon the plate. The block is then turned 180° and a second reading of M^1 is taken. One half of the difference between the two readings will measure the distance of the defining line on the block from the middle point between two stops when contacts are made with the end surfaces. If the plate K is moved forward a distance equal to

$$\left[\tfrac{1}{2}\text{ inch} + \frac{M_1^1 + M_2^1}{2}\right],$$

the micrometer line of the microscope will be in the perpendicular plane which passes through the point of contact formed when the two stops are brought together by the removal of the block.

In the same manner the reference line of micrometer M is brought into coincidence with the plane passing through the point of contact of the stops at the other end. The distance between the micrometer lines of the two microscopes is now equal to the length of the end-measure standard.

(4.) The line-measure standard to be compared is now placed upon the table S, and the distance between the defining lines of the meter is compared with the distance indicated by a constant plus the readings of the microscope micrometers. The adjustments required are the same as those described under division (*a*), page 302.

The comparison of short-end measure gauges can be expeditiously made by means of the graduated reference-bar attached to the stop-plate. For this purpose the two lower slides are brought near enough together to allow the stops of the upper plates to be brought into contact. Both slides are then securely fastened to the cylindrical ways upon which they rest, and one of the stop-slides is securely clamped also. After contact has been made between the free and the fixed stops, the micrometer line of the microscope is brought into coincidence with the defining line at one end of the bar attached to the free stop-plate. The end gauge is then placed between the stops, the free slide being moved back the required distance in order to allow the insertion. During this operation the microscope remains undisturbed, and the graduated bar passes under it without disturbance of the focal plane. The difference in the readings, therefore, for the two positions of the free stop-plate, i. e. before and after the insertion of the end gauge, measures its deviation in length from the line standard. If three microscopes are mounted upon plate K, and one of the stop-plates is attached to the front face of the carriage in such a manner that the two stops are parallel with the cylindrical ways, the method of comparison already described is applicable, and conditions (1) and (2) are both fulfilled.

The sixth condition is met in two ways.

(1.) By the use of the two stops, H, H[1], Fig. 4.

The stops are first set approximately at the distance apart indicated by the subdivisions to be compared. The method of comparing each space with the constant distance between the stops is the same in every respect as that described already. The following example is given in illustration.

COMPARISON OF INCH SUBDIVISIONS OF $G_2^{a_2}$.

Space.		*L*	*R*	*R* — *L*	(*R* — *L*) *minus* Constant.	Σ
1	5 rev.	0.4 div.	3.8 div.	+3.4 div.	—2.7 div. = —1.4 μ	—1.4 μ
2	....	0.0 div.	8.3 div.	+8.3 div.	+2.2 div. = +1.1 μ	—0.3 μ
3	....	0.6 div.	5.7 div.	+5.1 div.	—1.0 div. = —0.5 μ	—0.8 μ
4	....	1.3 div.	7.9 div.	+6.6 div.	+0.5 div. = +0.3 μ	—0.5 μ
5	....	1.0 div.	9.7 div.	+8.7 div.	+2.6 div. = +1.3 μ	+0.8 μ
6	....	1.1 div.	5.5 div.	+4.4 div.	—1.7 div. = —0.8 μ	+0.0 μ
			Mean	+6.1 div.		

In this comparison the distance between the stops was 6.1 div. less than the average value for one inch. When this constant is subtracted from the separate values of *R* — *L*, the residuals represent the relative values of the separate subdivisions. With the microscope of Comparator No. 1 a positive residual indicates that the measured space is too short. In this case the first space is 1.4 μ relatively too long, and the second 1.1 μ relatively too short. In order to obtain the error of any line reckoned from the first line, we must sum the residuals algebraically. Here the first five inches are 0.8 μ too short.

(2.) By the use of two microscopes.

It will be seen in Fig. 1 that there are two carriages, S and S¹, which traverse independent ways. S¹ is supposed to be in front of S. Two arms are attached to the upper surface of table S¹ (not shown in the figure), which project about half-way over the surface of S, allowing a slight clearance between the two surfaces. The standard whose subdivisions are to be compared is placed upon the table S, and a bar having upon its surface a graduated space, X, approximately equal to one of the subdivisions of the first bar, is placed upon the projecting arms attached to S¹. Both microscopes are now secured to the carriage K. M¹ is adjusted for coincidence with the initial line of the standard, which is placed upon S, and M is adjusted for coincidence with the corresponding line upon the other bar. The carriage K is moved toward the left, and a second coincidence of M is made with the other defining line. A comparison of the two readings of M¹ for the two positions of M will give the relation between the two spaces compared. M¹ is then adjusted for coincidence with the second line, and the carriage S¹ is carried back by the rack and pinion D till the first line is again under M. The second subdivision can now be compared with the same constant space, X, as before. It is obvious that, by the proper disposition of the two bars with respect to M and M¹, subdivisions of any magnitude whatever can be compared. It is to be noted, however, that the results obtained in this way are subject to errors due to the horizontal curvature of the cylindrical ways.

(3.) For long distances, and for any distance exceeding one decimeter, more reliable results can be obtained by the use of two microscopes in a fixed position. The various adjustments required in order to bring the defining lines of any subdivision into coincidence with M and M¹ have already been described.

Description of Comparing-Rooms.

The comparator first described is mounted upon isolated brick piers in the cellar of the Observatory. Through the liberality of the Director of the Observatory a small room in the shape of a trapezium was partitioned off for this purpose. This comparator was at first mounted upon stone piers mounted upon the clock pier in the prime-vertical room of the Observatory. But notwithstanding the great size and stability of this pier, it was found impossible to make comparisons except very early in the morning before the disturbance from passing teams began. This pier rests upon a layer of blue clay having a large inclination to the horizon. Beneath there is a layer of sand. The tremors communicated to the clock pier through this combination were found to be surprisingly great. The tremors produced by ice-carts at the distance of 1,000 feet rendered it impossible to make exact comparisons. The heavy steps of an assistant could be counted to the distance of 100 feet, by noticing the effect of the concussion upon the pier, which was in turn communicated to the surface of the bar examined under the microscope.

Heat is communicated to this comparing-room from the furnace in the cellar by a pipe which enters the room near the ceiling and nearly over the comparator. Under certain circumstances the temperature in this room may be kept under very good control, but great care has been found necessary in this regard. The comparator is directly in the line of the windows. By opening both windows during the night, the temperature within the room is found to be reduced nearly to the temperature of the outside air. By making the observations with this comparator on cloudy days and early in the morning, much better results have been obtained than were expected.

By the liberality of the President of Harvard College, comparing-room No. 2 was fitted for the reception of the Universal Comparator. It is situated in the basement of Harvard Hall. The dimensions of the room are 12 feet in length, 9 feet in width, and 8 feet in height. The brick walls which surround the room are twelve inches in thickness. The brick piers upon which the comparator rests extend to a depth of eight feet. The walls, the ceiling, and the floor are all double-planked, with two intervening air spaces. Between the inner and the outer partition there is a layer of rosin-soaked paper. The room has double windows and double doors. The steadiness of the temperature within the room may be inferred from the record on pp. 366–371. During the summer of 1882 the extreme change of the Fahrenheit thermometer for eight weeks was 1°.3. During the same time the daily variation in the temperature of the outside air often amounted to 25°.

Between April 14 and June 1, 1883, the extreme range was 0°.75 C. On June 3 the temperature of the room was raised by artificial means. By June 5 the temperature had reached the stationary point, viz. 17°.07 C., and between this date and June 28 the rise was only 0°.96. On July 6, the reading of *Y* 61 was only 18°.48, notwithstanding the average temperature of 31° for the two preceding days. On July 7, the room was exposed to the open air.

An attempt has been made to produce desired variations of temperature by the following arrangement, which has been found to be moderately successful. Sheets of galvanized iron three feet in width, after having been fastened at the edges by soldering, and riveted together at intervals of twelve inches, were fastened to the inner walls of the room in such a manner that there is a gradual decline in their height above the floor. They are connected together by rubber tubing. In the opposite room a tank is arranged for either hot or cold water, which is connected with the reservoir at the highest point. At the lowest point there is an outlet through the walls of the room. Either hot or cold water entering this reservoir of narrow section slowly percolates through the enclosed space, and flows off through the outlet, maintaining a nearly constant supply of either hot or cold air within the room. The reservoir holds about five gallons, and the amount of surface exposed on one side is about 100 square feet.

This comparing-room has one fault in construction which has given considerable trouble, and which it has been found impossible to remedy entirely. In order to be able to raise the comparator as high as the window, it was found necessary to give the piers a height of four feet. The head of the observer is therefore very near the ceiling. This difficulty has been partly remedied by a large trap-door in the ceiling, which allows the heat developed by the presence of the observer to enter the space between the partitions.

Description of the Thermometers employed in the Comparisons.

Throughout the entire series of observations the Yale College standard has been adopted. In the earlier part of the work a Fahrenheit thermometer graduated to fifths of degrees was used. It is designated *O*. It was purchased of a dealer in New York at a low price, but it was found to be an exceptionally fine instrument. Its error was determined by Dr. Waldo, by comparison with the Yale standard. It was afterwards carefully compared with Cassella No. 3235, which had been rigorously compared with the air thermometer of Professor Rowland by Mr. S. W. Holman of the Massachusetts Institute of Technology. The independent comparisons of Dr. Waldo and of Mr. Holman agree in giving the same tenth of a degree for every point compared. The corrections adopted are given below.

T	*O*	3235	*T*	*O*	3235
°	°	°	°	°	°
32	—0.74	—0.80	60	—0.90	—0.94
35	—0.70	—0.81	65	—0.98	—0.95
40	—0.70	—0.84	70	—0.98	—0.97
45	—0.71	—0.86	75	—0.92	—0.97
50	—0.75	—0.89	80	—0.93	—0.98
55	—0.79	—0.91			

As a check upon the observations with *O*, a Centigrade thermometer, marked No. 1, was read in connection with it. The corrections to No. 1 were found from a comparison with *O* to be as follows: —

T	No. 1	*T*	No. 1	*T*	No. 1
°	°	°	°	°	°
0	—0.50	12	—0.94	21	—0.72
3	—0.67	15	—0.97	24	—0.50
6	—0.78	18	—0.90	27	—0.63
9	—0.90				

The standard designated *Y* 61 was received from Dr. Waldo in October, 1882. Since this date all comparisons have been made with reference to this standard. The following Report accompanied the standard: —

"THE OBSERVATORY OF YALE COLLEGE. — THERMOMETRIC BUREAU.

"*Examination of the Y. O. S. Thermometer, No.* 61, *made by Tonnelot.*

"1st. This thermometer has been examined in a vertical position with the metallic scale and tube immersed in water having the temperature of the bulb.

"2d. When the correction is + it must be added to the thermometer reading, and when — it must be subtracted. For example, suppose the thermometer to register 81°.0 and the respective tabular corrections at 72° and 92° to be —0°.5 and —0°.7, then the corrected reading of the thermometer would be 81°.0 — 0°.6 = 80°.4.

"The theoretical mercurial standard thermometer to which this instrument has been referred, is graduated by equal volumes upon a glass stem of the same dimensions and chemical constitution as the Kew standards 578 and 584. The permanent freezing point is determined by an exposure of not less than forty-eight hours to melting ice, supposing the temperature of the standard has not been greater than 25° C. = 77° F. during the preceding six months. The boiling point is determined from the temperature of the steam of pure water at a barometric pressure of 760 mm. = 29.922 in. (reduced to 0° C.) at the level of the sea and in the latitude of 45°. This standard coincides with the perfect gas thermometer within 0°.1 F. for temperatures between zero and 212° F.

"LEONARD WALDO,
Astronomer in Charge.

"New Haven, Conn., March–October, 1882.

"YALE OBSERVATORY STANDARD NO. 61. — O. T. S., OBSERVER.

Reading of Y. O. S. 61.	Correction to be applied.	Depression at 0° for 100° Elevation.	Reading of the 0° point when horizontal.	Correction depending on Calibration.
°	°	°	°	°
0.0 C.	0.00	—0.20	+0.04	0.00
5.0	—0.06			
10.0	0.00			
12.5				+0.17
15.0	+0.02			
20.0	+0.07			
25.0	+0.12			+0.33
30.0	+0.16			
35.0	+0.18			
37.5				+0.36
40.0	+0.13			
45.0	+0.20			
50.0	+0.12			+0.41
55.0	+0.14			
60.0	+0.20			
62.5				+0.54
65.0	+0.16			
70.0	+0.28			
75.0	+0.21			+0.45
80.0	+0.20			
85.0	+0.13			
87.5				+0.29
90.0	+0.02			
95.0	—0.02			
100.0	+0.07			0.00

"1. The first column gives the scale readings on the thermometer.

"2. The second column gives the sum of all the corrections to be applied at the points of the scale indicated in 1, to reduce the readings to the standard of this Observatory.

"3. The third column gives the depression of the zero point caused by heating the standard to 100° C.

"4. The fourth column gives the reading of the zero point when the standard is inclined 90°.

"5. The fifth column gives the correction depending on the interior figure of the standard column."

It will be noticed that the report of Dr. Waldo gives only the corrections of *Y* 61 between the limits 0° and 100°. In the reduction of the observations at temperatures below 0° for the determination of the absolute coefficients of expansion of the bars under consideration, I found a constant tendency to a positive correction, on the supposition that the coefficient was constant. For example, instead of finding the constant difference between bars *T* and *S* in melting ice to be 75.1 div., as determined from the equations of condition on the following pages, I found continually diminishing values, until for *Y* = —11° the value was 52.6 div. In the case of bar *C. S.* a similar result was found. The coefficients were now assumed to be a constant, and the corrections to the thermometer required to make all the values of *S* — *T* and *S* — *C. S.* below 0° agree with the values derived from observations above 0° were computed, with the following results.

Corrections to Y 61.

Y 61	From *T*	*Y* 61	From *T*
—10°.8	+0°.35	—4°.5	—0°.02
—10.4	+0.18	—3.6	—0.01
— 9.9	+0.20	—2.1	+0.06
— 7.9	+0.13	—1.2	—0.04
— 7.0	+0.03	—0.7	—0.07
— 6.1	+0.10	—0.5	+0.05
— 4.6	+0.03	—0.4	+0.01

A similar series of corrections was derived from bar *C. S.* Smooth curves were now drawn through the points determined by these residuals, and the following corrections were obtained. Afterwards Mr. S. W. Holman, of the Institute of Technology, compared *Y* 61 with an alcohol standard thermometer by Baudin. His results are given below. It should be noted that Mr. Holman's values were derived before he had any knowledge of the results obtained by the writer.

Y 61.	From *T*	From *C. S.*	Mean.	Holman.	Adopted Corrections.
c	°	°	°	°	°
—1	—.02	+.09	+.03	+.03	+.03
—2	—.02	+.14	+.06	+.06	+.06
—3	—.01	+.18	+.09	+.09	+.09
—4	+.01	+.22	+.12	+.13	+.13
—5	+.04	+.22	+.13	+.13	+.13
—6	+.06	+.22	+.14	+.14	+.14
—7	+.14	+.22	+.18	+.15	+.16
—8	+.20	+.23	+.22	+.18	+.20
—9	+.30	+.24	+.27	+.24	+.25
—10	+.40	+.26	+.33	+.31	+.32
—11	+.48	+.32	+.37	+.39	+.38

The writer is using at the present time in connection with *Y* 61 a spirit thermometer made by Mr. J. S. Huddleston of Boston. The length of each degree Centigrade is about 2.5 centimeters, and the length of the column of (colored) alcohol is about thirty-nine inches. The complete determination of the errors of this thermometer will need to be deferred till the coming winter; but according to the present indications it is an instrument of extraordinary precision. The greatest deviation thus far observed from the corrected readings of *Y* 61 is about 0°.06.

DESCRIPTION OF MICROSCOPES.

VALUES OF ONE REVOLUTION OF MICROMETER SCREWS.

The measuring microscope used in connection with Comparator No. 1 has a tube fourteen inches in length. The micrometer was made by Powell and Leland.

Nearly all of the observations have been made with a Tolles four-system inch. The illumination is invariably obtained by the use of a prism inserted between the two front lenses, a device known as Tolles's opaque illuminator. The principle of this illuminator is so often stated incorrectly, that it is well to restate it here. The focus of the rays of light which pass through the prism is a little outside of the focus of the objective itself. The image under the objective, therefore, is *within* a cone of diffused light, the axis of the cone being in the line of collimation of the objective. This condition, however, requires a somewhat careful adjustment of the prism when it is set by the maker.

The illumination of polished metal surfaces is simply perfect. Sky illumination gives better results than artificial illumination. The distance of the objective from the opening through which the light passes may be as great as 100 feet. It is only necessary that the plane face of the prism shall be directed towards the source of light. In order to get the best results, the power of the objective should be as great as the equivalent of an inch lens. But if an objective of great working distance is required, a large prism may be mounted in front of the lens. The writer has made use of this method of illumination for the microscopes of the Harvard College Meridian Circle with good success. The focal length of these objectives is four inches.

The following are the results of the various determinations of the values of the micrometer screws.

Comparator No. 1, Microscope A,
1 inch objective.

1880, Apr. 25	1 div. =	0.505μ
1880, Apr. 26	"	0.504
1882, June 8	"	0.503
1882, Oct. 15	"	0.504
1883, Feb. 26	"	0.505
1883, Feb. 28	"	0.504
Mean,		0.504

Universal Comparator, Microscope A,
1 inch objective.

1882, Oct. 15	1 div. =	0.438μ
1883, Mar. 23	"	0.441
1883, Mar. 29	"	0.441
1883, Apr. 5	"	0.442
1883, Apr. 6	"	0.440
Mean,		0.440

It will not escape attention that no mention has thus far been made of any arrangement for protecting the standard bars to be compared from the effect of the increase of temperature due to the presence of the observer in the comparing-room. The omission has not been accidental.

The common impression, that the effect of such increase of temperature will be immediately apparent, is erroneous. If the meter is traced upon a thin ribbon of steel, any increase of temperature amounting to 10° will produce the change in length which its coefficient of expansion demands, within 15 or 20 seconds; but if its mass be increased two hundred fold, a change in temperature of the same amount will require from one to two hours for its normal action.

The preparatory work which needs to be done with every bar which is to receive standard graduations is the determination of the time required for a given change of temperature to produce its full effect. This time is a function of the shape and the mass of the bar. It is proposed during the approaching winter to make an exhaustive study of this element for the bars under consideration. The few observations which have already been made seem to show that, if these bars are quickly removed from a temperature of 32° to a constant temperature of 62°, the times required for them to reach their normal length will be about as follows: —

T	requires from 15 to 20 minutes.
$C. S.$	requires from 30 to 40 minutes.
R_1	requires about 2 hours.
R_2 and G	require about 4 hours.

Conversely, the times within which an increase of temperature amounting to one degree, *as indicated by the thermometer*, will be inappreciable in the comparisons, are about as follows: —

T	4^m
$C. S.$	10^m
R_1	12^m
R_2	18^m
G	22^m

The Tresca bar, T, seems to possess decided advantages over every other form for the usual conditions under which observations are made. However sudden the change of temperature, and however great the amount of the change, the thermometer will indicate the true length of the bar, if an observed temperature can remain constant for about eleven minutes after the mercury reaches the stationary point. On the other hand, standards having a large cross-section are to be preferred, if a constant temperature can be maintained for several hours, since the effect of any change can be neglected for a considerable time.

Instead, therefore, of arranging protecting screens for the comparator, I have endeavored to arrange the adjustments in such a manner that a complete set of comparisons can be made before the heat developed by the presence of the observer could produce any effect. In the comparisons described in this paper, the bar T, having the least mass, is placed in front, and the microscopes are left in adjustment upon the defining lines from the previous observation. The time required to complete the observations upon this bar is not, therefore, over one or two minutes. Bar $C. S.$, being the next in order of mass, is observed next in order of time, and bar R_2, having the greatest mass, is observed last. *But after the observations are completed, the comparing-room remains closed for at least four hours.* During this time, the increase of temperature due to the presence of the observer, which is usually about 0°.4 C., will have become absorbed in the general temperature of the room, and the several bars will have reached a state of rest as far as this special increase is concerned.

We are now prepared to enter upon an examination of the standard prototypes described in this paper. The various comparisons will be given nearly in the order in which they were made.

COMPARISON OF YARD $R_2^{a_2}$ WITH “BRONZE 11” AT WASHINGTON.

Professor Hilgard having kindly consented to undertake the comparison of the bronze yard $R_2^{a_2}$ with “Bronze 11,” Assistant Edwin Smith was assigned to this work. The observations by Mr. Smith were made with the Lane vertical comparator. At his request, the writer made independent micrometer readings, after all the adjustments had been made, but there was a complete avoidance of any knowledge of the results obtained.

The full text of Professor Hilgard's report will be found in the report by the writer to the Pratt and Whitney Company, relative to the standards constructed for them; but the portion relating to R_2 is given here.

Date.			Temperature. F.	“Bronze 11” — R_2.	
				Smith.	Rogers.
1881	h	m	°	in.	in.
Jan. 26	9	49 A M.	56.20	—.000116	—.000100
“	11	21 “	56.15	—.000114	—.000089
“	1	28 P.M.	56 20	+.000004	+.000022
“	3	11 “	56.35	—.000060	—.000084
Jan. 27	9	39 A.M.	55.90	+.000063	+.000052
“	11	24 “	55.55	—.000002	—.000014
“	1	23 P.M.	55.10	—.000140	—.000125
“	3	10 “	56.40	—.000133	—.000098
Jan. 28	9	36 A.M.	52.00	—.000064	—.000072
“	11	22 “	51.75	—.000041	—.000041
“	12	36 P.M.	51.30	—.000018	......
“	2	16 “	51.30	+.000015	......
Smith			54.37	—.000050	......
Rogers			54.98	......	—.000055

At 54°.70 F. “Bronze 11” — R_2 = —0.000052 inch.

Y — “Bronze 11” = +0.000088 “

$Y - R_2$ = +0.000036 “

I am indebted to the courtesy of Professor Hilgard for the opportunity of comparing R_2 with "Bronze 11" upon Comparator No. 1, which was sent to Washington for this purpose. Since subsequent comparisons were to be made with this comparator, it seemed important that the relations between these standards should be determined under the same conditions as those under which future investigations would be made.

For this work I was assigned to a room in the basement of the building, in which a pretty steady high temperature could be maintained. Afterwards the comparator was removed to a small observatory building in the rear, which was admirably adapted for the purpose. Here a nearly constant low temperature was maintained for three days. The comparator was then mounted again in its former location, and further observations were made at a nearly constant temperature, which had now become reduced to about 62°.

The following are the results of the comparisons.

Date.	Observer.	Thermometer.	"Bronze 11" *minus* $R_2^{a_2}$.
1881		°	in.
Feb. 1 A.M.	R.	35.2	—.000039
" 1 "	R.	35.2	+.000028
" 1 P.M.	R.	35.6	—.000002
" 1 "	R.	35.6	—.000083
" 2 A.M.	R.	30.9	—.000014
" 2 "	S.	30.9	—.000030
" 4 P.M.	R.	60.9	—.000015
" 7 "	R.	62.2	—.000059
		Mean....	—.000027

We have, therefore,

$$\text{"Bronze 11"} - R_2^{a_2} = -0.000027 \text{ inch.}$$

$$\text{"Bronze 11"} - Y = -0.000088 \quad \text{"}$$

$$R_2^{a_2} - Y = -0.000061 \quad \text{"}$$

Finally,

$$R_2^{a_2} + \frac{0.000036 \text{ in.} + 0.000061 \text{ in.}}{2} = Y.$$

Or,

$$R_2^{a_2} + 0.000048 \text{ in.} = Y.$$

Since the metal in each bar has the same composition, it is assumed that they have the same coefficient of expansion.

Comparisons were also made between the Tresca meter and the Coast Survey meter "No. 49," which bears a known relation to the Berlin meter, and thence with the Metre des Archives.

The following equations of condition were obtained.

Date. 1881	"49" — T^{a_2}			$(\tau - 32°)$	"49" — T^{a_2} at 32°	Δa
Jan. 24	$+139.4\,\mu$	$=$	a	$-40.2\,b$	$+90.0\,\mu$	$-1.7\,\mu$
" 24	$+140.1\,\mu$	$=$	a	$-40.3\,b$	$+90.5\,\mu$	$-1.2\,\mu$
" 24	$+138.6\,\mu$	$=$	a	$-40.3\,b$	$+89.0\,\mu$	$-2.7\,\mu$
" 24	$+140.3\,\mu$	$=$	a	$-40.5\,b$	$+90.5\,\mu$	$-1.2\,\mu$
" 25	$+139.6\,\mu$	$=$	a	$-37.8\,b$	$+93.1\,\mu$	$+1.4\,\mu$
" 26	$+140.9\,\mu$	$=$	a	$-38.3\,b$	$+93.8\,\mu$	$+2.1\,\mu$
" 30	$+\ 96.2\,\mu$	$=$	a	$-\ 4.2\,b$	$+91.0\,\mu$	$-0.7\,\mu$
" 31	$+\ 96.0\,\mu$	$=$	a	$-\ 3.3\,b$	$+91.9\,\mu$	$+0.2\,\mu$
Feb. 1	$+\ 95.4\,\mu$	$=$	a	$-\ 4.1\,b$	$+90.4\,\mu$	$-1.3\,\mu$
" 2	$+129.1\,\mu$	$=$	a	$-30.4\,b$	$+91.8\,\mu$	$+0.1\,\mu$
" 6	$+131.0\,\mu$	$=$	a	$-29.4\,b$	$+94.8\,\mu$	$+3.1\,\mu$

Normal Equations.

$$+1386.6 = +11\,a - 308.8\,b \qquad b = +1.23\,\mu$$
$$-42076.8 = -308.8\,a + 11234.1\,b \qquad a = +91.7\,\mu$$

It will hereafter be shown that at 32°

$$T^{a_2} + 102.8\,\mu = A.$$

But
$$\text{“49”} - T^{a_2} = 91.7\,\mu.$$

Hence
$$\text{“49”} + 11.1\,\mu = A.$$

Förster gives for "49" the following relations: —

From the direct comparison of the Berlin meter with the Metre des Archives,

$$\text{“49”} + 21.4\,\mu = A.$$

From a comparison of the Berlin meter with the meter of the Conservatory,

$$\text{“49”} + 5.2\,\mu = A.$$

It will be seen that the value found in terms of the Tresca meter falls between these values.

Since the absolute coefficient of expansion of "49" has been determined both by Förster and by Pierce, the relation here obtained between T and "49" will yield a value for T. We have for "49," for each degree Centigrade,

Förster,	$18.69\,\mu$.
Pierce, direct,	$18.83\,\mu$.
Pierce, indirect,	$18.81\,\mu$.

Reducing the value $b = 1.23\,\mu$ to its equivalent for one degree Centigrade, we have the following values for the absolute coefficient of T: —

From comparison with Förster, $16.48\,\mu$.
" " Pierce, $16.60\,\mu$.
" " Pierce, $16.62\,\mu$.

It will be seen that these values are somewhat larger than the value derived from the observations which follow; but it can hardly be expected that the correct relation between T and "49" could be obtained from the limited number of observations here given.

COMPARISON OF THE FROMENT END-METER F_e WITH T^{a_2} WITH COMPARATOR NO. 1.

Date. 1880.	T (Fahr.)	$T^{a_2} - Fe$	* $b = 3.40\,\mu$ $T^{a_2} - Fe$ at 32° Fahr.	Mean values.
Nov. 19	47°.6	$+\ 53.3\,\mu$	$+106.3\,\mu$	
" 22	47.1	$+\ 54.6\,\mu$	$+105.9\,\mu$	
" 24	19.1	$+158.0\,\mu$	$+114.1\,\mu$	
" 25	33.9	$+109.2\,\mu$	$+115.7\,\mu$	
" 28	76.1	$-\ 44.8\,\mu$	$+105.1\,\mu$	
" 29	45.3	$+\ 66.0\,\mu$	$+111.6\,\mu$	$109.8\,\mu$
Dec. 1	57.3	$+\ 19.1\,\mu$	$+105.1\,\mu$	
" 17	37.4	$+\ 90.0\,\mu$	$+108.4\,\mu$	
" 19	35.4	$+\ 10.2\,\mu$	$+113.8\,\mu$	
" 21	38.9	$+\ 84.4\,\mu$	$+107.9\,\mu$	
" 22	46.1	$+\ 58.8\,\mu$	$+106.7\,\mu$	
" 24	34.6	$+105.6\,\mu$	$+114.4\,\mu$	$109.4\,\mu$
" 26	49.6	$+\ 51.9\,\mu$	$+111.7\,\mu$	
" 27	51.5	$+\ 40.8\,\mu$	$+107.1\,\mu$	
" 28	39.8	$+\ 86.9\,\mu$	$+113.4\,\mu$	
" 29	19.2	$+157.4\,\mu$	$+113.9\,\mu$	
" 31	5.0	$+204.4\,\mu$	$+112.6\,\mu$	
1881. Jan. 4	52.9	$+\ 34.9\,\mu$	$+106.0\,\mu$	$110.8\,\mu$

We have, therefore, for 0° C.,

$$T^{a_2} - F_e = +110.0\,\mu.$$

But $F_e - A = +\ 8.4\,\mu.$

Whence $T^{a_2} - A = +101.6\,\mu.$

According to Tresca $T^{a_2} - A = +102.8\,\mu.$

Diff. $= 1.2\,\mu.$

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* This value of b is the final value derived from the investigation on the following pages.

Comparison of the Tresca Meter $T_1^{a_2}$ with the Line-Meter F_e with Comparator No. 1.

1881.	$(\tau - 0^\circ)$ C.	$T^{a_2} - Fe$	$b = 3.40\,\mu$ at 0° C. $T^{a_2} - Fe$
Apr. 25	+16.5	+ 3.2 μ	+104.2 μ
" 26	+12.3	+25.6 μ	+101.1 μ
" 27	+13.1	+23.2 μ	+103.4 μ
" 27	+15.7	+ 6.8 μ	+102.9 μ
" 28	+11.5	+32.4 μ	+102.8 μ
" 28	+13.6	+18.3 μ	+101.5 μ
" 29	+10.8	+36.0 μ	+102.0 μ
" 29	+18.7	—12.0 μ	+102.4 μ
May 2	+10.2	+39.4 μ	+101.4 μ
" 2	+12.5	+34.4 μ	+100.9 μ

We have, therefore, for 0° C.,

$$T^{a_2} - F_e = 102.3\,\mu.$$

But

$$T^{a_2} - A = 102.8\,\mu.$$

Hence

$$F_e - 0.5\,\mu = A.$$

This relation has an importance far beyond any ordinary comparison of standards, since the centimeter derived from the Froment line-meter is the unit upon which Angstrom's wave lengths depend. It is besides the basis of nearly all the later physical investigations undertaken in France. If, therefore, the transfer of this meter to the surface of bar *F* is assumed to be without error, the correspondence of the whole unit with the Metre des Archives is nearly perfect.

Comparison between Meters T and R_2.

After my return from Washington, two series of comparisons between these standards were instituted, one series with Comparator No. 1, and the other with the Universal Comparator. In the first series two microscopes were used, being attached to the carriage. The bars were placed at a distance $2x$ centimeters apart, and observations were made for the positions $+x$ and $-x$.

For $x = +3.0$ cm.

Date. 1881.	$(\tau - 62.^\circ0)$ F.	$T^{a_2} - R_2^{a_2}$	At 62°.0 F. $T^{a_2} - R_2^{a_2}$
Feb. 14	+24.1	+177.7 μ	+164.0 μ
" 15	+23.5	+177.2 μ	+163.8 μ
" 16	—12.2	+152.2 μ	+159.2 μ
" 17	—13.2	+151.0 μ	+158.5 μ
" 20	+32.5	+185.4 μ	+166.9 μ
" 21	+22.2	+172.2 μ	+159.6 μ

Date. 1881.	$(\tau - 62.^{\circ}0)$ F.	$T^{a_2} - R_2^{a_2}$	$T^{a_2} - R_2^{a_2}$
Feb. 22	—13.7	+145.5 μ	+153.3 μ
" 23	—13.7	+142.8 μ	+150.6 μ
Mar. 16	— 8.9	+147.5 μ	+152.5 μ
" 23	—13.6	+144.6 μ	+152.3 μ
" 24	— 9.7	+154.0 μ	+165.2 μ
" 25	+26.8	+178.9 μ	+163.7 μ
" 29	—11.8	+155.0 μ	+161.7 μ
" 30	—13.2	+151.3 μ	+158.8 μ
" 31	—15.4	+151.0 μ	+159.7 μ
Apr. 3	+29.3	+187.2 μ	+160.5 μ
" 8	+ 6.9	+165.0 μ	+161.1 μ
" 10	+ 8.9	+167.6 μ	+162.6 μ

For $x = -3.0$ cm.

Feb. 24	—16.3	+165.5 μ	+174.7 μ
" 25	+35.9	+197.8 μ	+177.4 μ
Mar. 11	+ 4.8	+174.7 μ	+172.0 μ
" 13	+23.1	+183.6 μ	+170.5 μ
" 14	+19.6	+186.1 μ	+175.3 μ
" 15	+22.4	+189.3 μ	+176.6 μ
" 16	— 9.0	+163.2 μ	+163.7 μ

We have, therefore,

$$\begin{aligned} & \qquad\qquad\qquad\quad T^{a_2} - R^{a_2} \\ \text{For } x &= +3.0 \text{ cm.} = +159.7\ \mu. \\ x &= -3.0 \text{ cm.} = +172.9\ \mu. \\ & \quad\ \text{Mean} = +166.3\ \mu. \end{aligned}$$

With the Universal Comparator.

EQUATIONS OF CONDITIONS BETWEEN T^{α_2} AND $R_2^{\alpha_2}$.

(With 1-inch objective.)

1 div. = 0.440 μ

Date. 1882.	$T^{a_2} - R_2^{a_2}$			$(\tau - 62^{\circ})$ F.	At 62° F. $T^{a_2} - R_2^{a_2}$	No. Obs.
Apr. 26	+401.5 div.	=	a	—16.30 b	+380.1 div.	3
" 27	+396.8 div.	=	a	—13.41 b	+379.2 div.	4
" 28	+391.7 div.	=	a	—12.15 b	+375.8 div.	5
" 30	+392.3 div.	=	a	—10.47 b	+378.6 div.	5
May 3	+393.9 div.	=	a	— 9.42 b	+381.6 div.	5
" 12	+380.0 div.	=	a	— 1.24 b	+378.4 div.	3
" 20	+372.8 div.	=	a	+ 2.98 b	+376.7 div.	3
" 23	+375.2 div.	=	a	+ 4.64 b	+381.3 div.	3

Normal Equations.

$$+3104.2 = +8\,a - 55.37\,b \qquad\qquad b = -1.31 = -0.58\ \mu$$

$$-22062.0 = -55.37\,a + 823.30\,b \qquad\qquad a = +378.9 = +166.0\ \mu$$

It will be seen that the value of b derived from these equations is nearly identical with the final value adopted from the subsequent observations, that value being $-0.57\,\mu$. Combining the value of $T^{a_2} - R_2^{a_2}$ with the value derived from the observations with Comparator No. 1, we have

$$T^{a_2} - R_2^{a_2} = \frac{166.3\,\mu + 166.0\,\mu}{2} = 166.1\,\mu.$$

The value derived from the observations which follow is $165.5\,\mu$.

Determination of Absolute Coefficients of Expansion.

The earlier experiments made by the writer in the determination of the absolute coefficients of expansion of the bars under consideration were very unsatisfactory. At first, the attempt was made to determine the coefficient of one end-measure bar by subjecting it to wide ranges of temperature when submerged in water, and thence to determine the relative coefficients between it and the remaining bars whose coefficients were desired. This attempt was only moderately successful. While it was possible to obtain nearly a constant value for the coefficient of this bar by different combinations of the results on the same day, the deviation of the values for different days was considerably greater than should have been found. The chief difficulty consisted in the impossibility of keeping the entire mass of the water at the same temperature. No amount of agitation seemed to accomplish this.

A second method gave rather better results. It was found that an end-measure bar placed in the clock-room of the Observatory remained at a nearly constant temperatue, the change during twenty-four hours rarely exceeding a few tenths of a degree. It was also found to be possible to place this bar upon Comparator No. 1, and to make a comparison with any line-measure bar in a little less than one minute. During this time the change in the length of the bar was found not to exceed two or three divisions of the micrometer, even when the difference in temperature was as great as 20° Fahr. The plan of observation was as follows. The line bar was adjusted for position upon the comparator, and the reading of the microscope for the contact of the stops and the coincidence with the defining line at one end was made under favorable conditions for a steady temperature. The reading of the thermometer was also recorded. The end-measure bar was then brought into the room, placed in position between the stops, and the microscope carriage was set for contact between the stops and the end of the bar. From this point the remaining part of the observation could be made leisurely for any temperature lower than that of the clock-room, since the relation of the microscope to the line bar would not be affected by a contraction in the length of the bar. Several pointings for coincidence with the other defining line of the meter were then made, after which the end-measure bar was returned to its former position. An interval of several hours was always allowed to elapse before a second comparison was made.

In the reduction of the observations, allowance was made both for the small deviation from a constant temperature in the end-measure bar, and also for the inferred rate of change between the time the bar was brought into the comparing-room and the time the observation for contact was made. Usually two or three contacts were made at intervals of thirty seconds, in order to obtain the observed rate of change.

Many observations of this kind were made, during the year 1881, for temperatures in the comparing-room ranging between 30° and 70°. The following values of the absolute coefficients were obtained. On account of the obvious imperfection of the method, it does not seem worth while to print the details of the work. It will be seen, however, that these values do not differ widely from those found from the method which will be presently described.

Absolute Coefficients.

For T, 16.58 μ. For R_1, 10.03 μ. For R_2, 17.55 μ.

The experience acquired in the observations thus far made was wholly in favor of the plan of deriving the coefficient of expansion of a line-bar for air contact, by comparison with an end-bar at a constant temperature. In no other way could an accurate comparison be so quickly made. But it is essential to the success of this method that the end-measure bar shall remain at a constant temperature during the entire series of comparisons with the line-standard at wide ranges of temperature. Only a few observations were needed to show that the end bar could be kept at an invariable temperature by keeping it constantly submerged in melting ice. It was found necessary to take only two precautions: first, that the bar should have a covering of ice about two inches in depth; and second, that the ice-trough should not remain in a high temperature for a longer time than about ten minutes. Experiment showed that, if there was too little ice in the trough in which the bar was submerged, the expansion beyond the normal length of 32° might amount to as much as 8 μ. It was also found that, if the ice-trough remained in the comparing-room at a high temperature for a time exceeding ten or fifteen minutes, an expansion amounting to about 5 μ was liable to occur, notwithstanding a vigorous stirring of the ice.

For the third series of observations the following preparations were made. A steel bar was prepared 6 mm. shorter than one meter. Steel plugs were inserted at each end, each having a projection of 3mm. The ends of the bar were then made as hard as possible, and the plugs were ground off till the defining surfaces were one meter apart. Careful and repeated observations showed that these end surfaces were truly parallel. The bar was then mounted in a trough of galvanized iron having a depth of 5 inches and a width of 5½ inches. The trough was originally prepared for a yard, and, in the first series of observations which follow, the bar, which is placed near the bottom of the trough, extends 4.5 cm. beyond each end. At the conclusion of the first series the trough was lengthened, and in the second series the projection at each end was only 3 mm.

In planning the execution of this series of observations, there were certain difficulties about the use of the Universal Comparator for this purpose which could not be easily remedied; and it was found necessary to make use of Comparator No. 1. Since it had been found that the Tresca bar *T* was extremely sensitive to small changes of temperature, and since it was possible to maintain a nearly constant temperature in the comparing-room of the Observatory for short intervals of time, it was arranged to determine the absolute coefficient of *T* by comparison with the bar *S* in melting ice, and then to determine the relative coefficients between *T* and the remaining standards from comparisons with the Universal Comparator.

Partly as an experiment, however, simultaneous observations for the absolute coefficients of bars R_2 and *C. S.* were made. A study of the tables which follow will show that the probable value of the results obtained is nearly proportional to the mass of the bars.

The various steps of the observations are as follows.

The line bar having been placed in position and adjustment upon the comparator during the afternoon, the comparing-room was closed till the next morning. During this time the temperature in the room generally became very steady. For low temperature observations, both windows were left open during the night. About sunrise the next morning the bar *S*, after having been submerged in melting ice for at least twenty minutes, was removed from the room in the cellar in which the pier of the Russian transit instrument is situated, and placed between the stops of the comparator. The comparison with the line-meters was then made in the manner already described. The ice-trough was then immediately removed to the cellar, and allowed to remain for a few minutes, when the operation just described was repeated, provided always that a steady temperature was maintained meanwhile in the comparing-room. The high temperatures in the comparing-room were produced partly by heat from the furnace, but a steady supply of heat was furnished from a gas stove, which was placed directly beneath the bed-plate of the comparator.

After the first series was completed, the trough was lengthened, and some changes were made in the disposition of the bar *S*, by which its apparent length was slightly changed. During the second series, the position of the stops was not disturbed, and the adopted order of observations was strictly followed in every case. This series, therefore, may be supposed to have greater weight than the first one. An attempt was made to make an equal number of observations for slightly increasing and slightly decreasing temperatures, in order to eliminate to a certain extent the difference between the temperature of the thermometer and the temperature of the bar; for it must always be understood that the thermometer simply registers its own temperature and not necessarily the temperature of the bar upon which it is placed. This arrangement was, however, only carried out to a certain extent.

There is one point in connection with these observations to which particular attention is called. If the contact surfaces of the bar *S* become worn by continual use, it is evident that a constant error will be introduced, which will need to be investigated before the observations for the coefficients of expansion can be reduced. But it will be seen from the observations which follow, that there is no conclusive evidence of such a change during the entire series. This result is certainly contrary to my expectations, especially as the force required to make the contacts secure is considerable. The trough containing the bar *S*, when filled with melting ice, weighs about twenty-five pounds, and this entire mass is required to be moved by the pressure of the stop attached to the microscope carriage. I conclude, therefore, that with ordinary care there is no danger of wear with steel surfaces which have received a temper as high as possible.

But in order te provide against this supposed source of error, the high and low temperature observations were made in close proximity.

After the observations for the absolute coefficients of the bars *T*, *C. S.*, and R_2 were completed, these bars, with R_1, were removed to the comparing-room in Harvard Hall. The series of observations for the relative coefficients between these bars extends from March 22 to June 28, 1883, but the series from which the equations of condition were formed terminated on June 7. A few subsequent observations were made as a check upon the results obtained from the equations.

The observations and reductions, both for the absolute and the relative coefficients, are given on the following pages.

COMPARISON OF LINE-METER T WITH END-METER S IN MELTING ICE WITH ONE-INCH OBJECTIVE.

(1 div. = 504 μ.)

SERIES I.

Date.	Y 61	$S - T^{b_1}$	Date.	Y 61	$S - T^{b_1}$
1883.	°	div.	1883.	°	div.
Feb. 7	+ 1.20	+ 25.7	Feb. 14	− 6.64	+278.4
"	+ 1.70	+ 30.4	"	− 7.18	+293.5
"	+ 1.70	+ 20.1	"	− 6.18	+270.3
"	+ 1.70	+ 24.5	"	− 6.03	+259.8
"	+ 2.60	− 12.5	"	− 6.04	+263.4
"	+ 4.20	− 60.0	"	− 7.60	+308.6
"	+ 3.40	− 38.7	"	− 7.56	+310.9
"	+ 3.40	− 34.5	"	− 6.06	+260.0
"	+ 4.50	− 76.0	"	− 6.66	+280.6
"	+ 7.65	−172.4			
			Feb. 15	+ 5.83	−118.4
Feb. 8	− 4.40	+213.8	"	+ 5.88	−116.9
"	− 4.30	+216.5	"	+ 5.90	−113.1
"	− 4.30	+219.4	"	+ 5.88	−120.6
"	− 4.50	+218.9	"	+ 5.90	−115.4
"	− 4.60	+220.4			
"	− 4.40	+217.7	Feb. 16	− 0.28	+ 75.6
"	− 4.40	+219.3	"	− 0.20	+ 82.1
"	+ 1.50	+ 18.6	"	+ 0.70	+ 55.8
"	+ 1.50	+ 15.5	"	+ 1.88	+ 17.9
"	+ 1.40	+ 16.4	"	+ 1.90	+ 16.7
"	+ 1.50	+ 19.2			
			Feb. 18	+28.78	−862.6
Feb. 9	− 4.70	+222.3	"	+28.80	−850.3
"	− 4.70	+228.0	"	+28.72	−863.7
"	− 4.80	+218.8	"	+28.44	−852.3
"	− 4.80	+218.9	"	+28.24	−847.4
"	− 4.70	+219.2	"	+28.58	−844.8
"	− 4.90	+221.3	"	+28.20	−837.2
			"	+28.56	−846.0
Feb. 11	+13.02	−342.6	"	+28.38	−838.3
"	+13.02	−343.5			
"	+13.92	−379.1	Feb. 19	+24.54	−720.2
"	+13.82	−375.1	"	+24.52	−726.4
			"	+24.24	−712.5
Feb. 12	+ 1.80	+ 20.4	"	+24.24	−704.0
"	− 2.94	+166.7	"	+24.24	−708.0
"	− 3.16	+171.3	"	+24.57	−719.7
"	− 0.48	+ 94.4	"	+24.57	−729.6
"	− 0.22	+ 81.3			
"	− 1.10	+ 98.4	Feb. 20	− 2.21	+142.8
"	− 1.48	+119.2	"	− 2.21	+139.9
			"	− 1.77	+128.4
Feb. 13	+ 2.38	+ 7.2	"	− 1.75	+120.6
"	+ 1.38	+ 26.2			
"	+ 1.38	+ 30.8	Feb. 25	+ 2.46	− 2.5
"	− 0.06	+ 79.0	"	+ 2.46	− 4.9
"	+ 0.04	+ 71.2	"	+ 3.48	− 32.9
"	+ 0.37	+ 61.9	"	+ 3.28	− 26.5
"	+ 3.30	− 26.8	"	+ 3.30	− 27.7
"	+ 3.30	− 26.1	"	+ 6.43	−129.8

SERIES I. — Continued.

Date.	Y 61	$S - T^{b_1}$	Date.	Y 61	$S - T^{b_1}$
1883.	°	div.	1883.	°	div.
Feb. 25	+ 7.80	—176.7	Feb. 27	— 9.96	+386.8
“	+ 7.80	—175.6	“	— 9.96	+379.0
“	+ 8.06	—174 1	“	— 6.87	+294.9
“	+ 8.06	—179.5	“	— 6.87	+291.1
“	+ 8.24	—182.2	“	— 6.88	+295.6
“	+ 8.24	—182.2	“	+ 2.64	— 12.8
“	+ 8.26	—191.2	“	+ 2.74	— 12.2
“	+ 8.64	—196.5	“	+ 2.80	— 10.5
“	+ 8.30	—188.4	“	+ 3.18	— 25.6
“	+ 8.34	—182.2	“	+ 3.20	— 23.7
“	+ 8 34	—182.8	“	+ 3.12	— 28.2
“	+ 8.46	—189.4			
			Feb. 28	— 3.73	+193.1
Feb. 26	+22.17	—642.5	“	— 3.73	+193.4
“	+21.95	—628.6	“	— 3.66	+192.0
“	+21.88	—635.4	“	— 3.66	+192.2
“	+21.86	—635.0	“	— 3.34	+185.1
“	+22.74	—658.4	“	— 3.34	+183.0
“	+22.72	—657.4	“	— 0.18	+ 80.1
“	+22.62	—659.1	“	— 0.18	+ 85.7
			“	— 0.28	+ 83.4
Feb. 27	— 9.82	+376.0	“	— 0.30	+ 86.3

SERIES II.

Date.	Time.	Y 61	$S - T^{b_1}$	Date.	Time.	Y 61	$S - T^{b_1}$
1883.	h. m.	°	div.	1883.	h. m.	°	div.
Feb. 28	6 0 A.M.	— 0.78	+ 77.3	Mar. 4	6 3 A.M.	— 0.14	+ 63.9
“	6 5 “	— 0.78	+ 91.5	“	6 20 “	— 0.28	+ 70.4
“	6 12 “	— 0.68	+ 93.9	“	6 24 “	— 0.30	+ 69.2
“	6 15 “	— 0.68	+ 91.6	“	6 40 “	— 0.52	+ 80.2
“	6 18 “	— 0.68	+ 84.8	“	6 43 “	— 0.52	+ 79.2
“	6 20 “	— 0.68	+ 82.4	“	7 0 “	— 1.18	+ 90.2
“	6 30 “	— 0.66	+ 81.8	“	7 3 “	— 1.15	+ 90.8
“	6 35 “	— 0.66	+ 87.0	“	8 0 “	+ 0.34	+ 50.5
				“	8 3 “	+ 0.34	+ 45.8
Mar. 1	3 30 P.M.	+ 3.64	— 56.5				
“	3 33 “	+ 3.64	— 52.3	Mar. 5	6 0 A.M.	— 5.08	+232.0
“	4 30 “	+ 3.68	— 57.6	“	6 5 “	— 5.08	+219.7
“	4 40 “	+ 3.72	— 54.8	“	6 30 “	— 3.92	+191.2
“	4 45 “	+ 3.72	— 53.0	“	6 35 “	— 3.94	+186.8
				“	7 0 “	— 1.26	+106.2
Mar. 3	8 25 A.M.	+19.26	—560.5	“	7 3 “	— 1.26	+ 99.3
“	8 30 “	+19 26	—561.1	“	7 10 “	— 1 22	+103.5
“	8 40 “	+19 28	—565.4	“	7 13 “	— 1.22	+101.2
“	8 50 “	+19.28	—562.5	“	7 30 “	— 1.18	+107.1
				“	7 33 “	— 1.18	+103.5
Mar. 4	7 20 A.M.	—10.34	+386.0				
“	7 25 “	—10.37	+386.4	Mar. 6	5 45 A.M.	— 7.98	+316.3
“	7 30 “	—10.45	+383.7	“	5 48 “	— 7.98	+304.7
“	7 50 “	—10.44	+386.5	“	6 0 “	— 7.75	+299.7
“	7 55 “	—10.40	+382.2	“	6 3 “	— 7.75	+299.7
“	6 0 P.M.	— 0.14	+ 63.8	“	6 12 “	— 7.77	+303.9

SERIES II. — Continued.

Date.	Time.	Y 61	$S - T^{b_1}$	Date.	Time.	Y 61	$S - T^{b_1}$
1883.	h. m.	°	div.	1883.	h. m.	°	div.
Mar. 6	6 15 A.M.	— 7.77	+294.3	Apr. 24	7 55 A.M.	+ 5.60	—118.5
"	6 30 "	— 7.79	+308.5	"	7 58 "	+ 5.65	—122.5
"	6 33 "	— 7.79	+304.5	"	8 0 "	+ 5.72	—120.8
"	7 0 "	— 7.90	+305.9	"	8 2 "	+ 5.72	—124.1
"	7 3 "	— 7.90	+308.4	"	8 5 "	+ 5.82	—121.7
"	7 20 "	— 8.34	+327.8	"	8 7 "	+ 5.85	—126.5
"	7 23 "	— 8.34	+324.5	"	8 12 "	+ 5.90	—125.7
				"	8 15 "	+ 5.98	—129.0
Apr. 15	7 0 A.M.	+19.47	—563.3	"	2 35 P.M.	+25.18	—748.4
"	7 30 "	+19.47	—567.7	"	2 50 "	+25.26	—750.5
"	7 30 "	+19.54	—565.1	"	3 5 "	+25.26	—750.4
"	8 10 "	+18.94	—547.1	"	3 7 "	+25.26	—749.5
				"	3 9 "	+25.30	—749.6
Apr. 17	7 0 A.M.	+12.24	—334.5	"	3 11 "	+25.30	—750.6
"	7 10 "	+12.22	—334.3	"	3 20 "	+25.28	—754.2
"	7 50 "	+12.44	—330.3	"	3 28 "	+25.28	—751.2
"	8 10 "	+12.06	—331.6	"	3 30 "	+25.28	—759.7
				"	3 40 "	+25.28	—756.7
Apr. 18	6 20 A.M.	+ 8.47	—210.2	"	3 45 "	+25.26	—753.8
"	6 23 "	+ 8.34	—200.0	"	3 50 "	+25.32	—753.7
"	6 27 "	+ 8.61	—219.4	"	4 0 "	+25.30	—750.3
"	6 30 "	+ 8.74	—215.4	"	4 3 "	+25.30	—749.5
"	6 45 "	+ 9.16	—230.9	"	8 50 "	+20.54	—604.0
"	7 10 "	+11.54	—307.7	"	8 55 "	+20.54	—598.9
				"	9 0 "	+20.42	—593.4
Apr. 19	8 0 A.M.	+ 7.66	—186.6	"	9 5 "	+20.40	—590.9
"	8 13 "	+ 7.84	—187.9	"	9 10 "	+20.36	—588.9
"	9 0 "	+ 9.70	—248.6	"	9 12 "	+20.28	—590.9
"	9 13 "	+ 9.48	—241.9	"	9 15 "	+20.28	—590.0
Apr. 20	8 0 A.M.	+17.88	—513.9	Apr. 25	6 30 P.M.	+ 2.46	— 19.2
"	12 0 "	+17.67	—504.9	"	6 33 "	+ 2.46	— 20.5
"	4 0 P.M.	+18.22	—531.5	"	6 35 "	+ 2.44	— 18.1
				"	6 38 "	+ 2.44	— 19.5
Apr. 22	5 40 P.M.	+ 4.24	— 77.4	"	6 45 "	+ 2.48	— 18.6
"	5 43 "	+ 4.24	— 76.3	"	6 48 "	+ 2.52	— 20.9
"	7 10 "	+ 4.94	— 94.9	"	6 55 "	+ 2.55	— 22.6
"	7 40 "	+ 5.10	— 99.0	"	7 5 "	+ 2.62	— 25.3
				"	8 20 A.M.	+ 3.85	— 61.6
Apr. 23	8 0 A.M.	+ 5.97	—130.6	"	8 25 "	+ 3.85	— 60.1
"	8 3 "	+ 5.97	—131.6	"	8 38 "	+ 3.85	— 62.8
"	8 20 "	+ 6.14	—135.2	"	8 42 "	+ 3.85	— 63.2
"	8 23 "	+ 6.14	—132.3	"	8 48 "	+ 3.70	— 56.4
"	8 37 "	+ 5.97	—127.8	"	8 50 "	+ 3.60	— 56.3
"	8 40 "	+ 5.97	—127.0	"	8 55 "	+ 3.70	— 62.1
				"	9 5 "	+ 4.00	— 64.5
Apr. 24	6 25 A.M.	+ 5.88	—128.7	"	2 45 P.M.	+19.80	—582.4
"	6 28 "	+ 5.95	—132.8	"	2 55 "	+19.74	—584.8
"	6 33 "	+ 6.05	—133.7	"	3 5 "	+19.76	—584.7
"	6 35 "	+ 6.10	—136.3	"	3 7 "	+19.76	—583.4
"	6 40 "	+ 6.16	—132.5	"	3 30 "	+20.10	—592.1
"	6 43 "	+ 6.20	—135.5	"	3 35 "	+20.04	—588.9
"	6 50 "	+ 6.22	—137.9	"	3 37 "	+20.04	—588.2
"	7 40 "	+ 5.52	—115.4	"	3 47 "	+20.05	—586.6
"	7 44 "	+ 5.52	—115.9	"	3 49 "	+20.03	—585.7

SERIES II. — Continued.

Date.	Time.	Y 61	$S - T^{b_1}$
1883.	h. m.	°	div.
Apr. 25	3 55 P.M.	+20°.10	−587.8
"	3 57 "	+20.10	−590.0
Apr. 26	7 10 A.M	+ 2.24	− 13.0
"	7 15 "	+ 2.24	− 16.7
"	7 20 "	+ 2.24	− 11.0
"	7 23 "	+ 2.24	− 11.3
"	7 29 "	+ 2.30	− 16.7
"	7 33 "	+ 2.30	− 16.4
"	12 5 P.M.	+21.04	−627.6
"	12 15 "	+21.22	−623.0
"	12 18 "	+21.22	−617.7
"	12 23 "	+21.12	−629.3
"	1 20 "	+21.23	−619.4
"	1 23 "	+21.23	−617.5
"	4 10 "	+25.90	−776.4
"	4 12 "	+26.07	−783.3
"	4 20 "	+25.86	−777.9
"	4 25 "	+25.86	−767.8
"	4 35 "	+26.00	−772.8
"	4 45 "	+26.10	−784.7
"	5 0 "	+25.84	−780.8
"	5 5 "	+25.84	−769.5
Apr. 27	6 40 A.M.	+ 5.44	−107.2
"	6 42 "	+ 5.44	−110.0
"	6 46 "	+ 5.66	−118.5
"	6 48 "	+ 5.66	−121.1
"	6 53 "	+ 5.86	−124.9
"	6 56 "	+ 5.86	−122.9
"	8 55 "	+ 8.84	−223.5
"	8 57 "	+ 8.97	−227.8
"	9 5 "	+ 9.15	−234.4
"	9 8 "	+ 9.20	−232.5
"	1 10 P.M.	+14.86	−416.4
"	2 5 "	+16.42	−468.2
"	2 7 "	+16.42	−469.3
"	2 15 "	+16.64	−475.8
"	2 17 "	+16.64	−472.9
"	2 30 "	+16.70	−478.8
"	2 33 "	+16.70	−478.3
Apr. 28	7 35 A.M.	+18.48	−534.2
"	7 38 "	+18.48	−534.0
Apr. 29	7 0 A.M.	+15.33	−431.1
"	7 3 "	+15.33	−430.2
"	8 15 "	+15.86	−449.7
"	8 17 "	+15.86	−449.4
"	8 37 "	+15.98	−455.1
"	8 40 "	+15.98	−454.4
"	8 55 "	+16.04	−457.8
"	8 58 "	+16.04	−458.2
"	9 3 "	+16.04	−452.5
"	9 5 "	+16.04	−454.2
1883.	h. m.	°	div.
Apr. 29	5 17 P.M.	+27°.32	−822.6
"	5 23 "	+27.28	−819.2
"	5 32 "	+27.44	−827.1
"	5 45 "	+27.62	−833.5
"	5 55 "	+27 62	−832.6
"	6 23 "	+27.46	−825.6
Apr. 30	6 45 A.M.	+ 3.28	− 43.4
"	6 50 "	+ 3.48	− 52.5
"	7 0 "	+ 4.06	− 63.8
"	1 0 P.M.	+15.88	−453.5
"	1 3 "	+15.88	−454.0
"	1 10 "	+15.86	−452.0
"	1 13 "	+15.86	−448.9
"	1 17 "	+15.80	−443.7
"	1 19 "	+15.80	−441.8
"	6 30 "	+18.02	−524.4
"	6 33 "	+18.02	−519.3
"	7 0 "	+17.74	−510.2
"	7 0 "	+17.74	−507.9
"	7 15 "	+17.50	−502.0
"	7 18 "	+17.50	−503.4
"	7 30 "	+17.60	−507.8
"	7 33 "	+17.60	−506.1
May 1	6 0 A.M	+ 5.41	−112.1
"	6 3 "	+ 5.41	−116.9
"	6 10 "	+ 5.50	−117.9
"	6 13 "	+ 5.58	−120.2
"	6 20 "	+ 5.82	−127.5
"	6 24 "	+ 5.82	−130.5
"	6 40 "	+ 6.26	−132.8
"	6 55 "	+ 6 48	−145.3
"	6 58 "	+ 6.50	−146.1
"	12 55 P.M.	+17.63	−507.9
"	1 0 "	+17.63	−504.4
"	1 10 "	+17.66	−503.5
"	1 13 "	+17.66	−504.2
"	7 20 "	+16.50	−473.9
"	7 23 "	+16.50	−475.3
"	7 30 "	+16.56	−469.9
"	7 33 "	+16.56	−472.6
May 2	7 0 A.M.	+ 8.70	−218.0
"	7 5 "	+ 8.80	−220.6
May 4	6 25 A.M.	+18.12	−518.5
"	6 28 "	+18.12	−513.7
"	6 30 "	+18 00	−513.5
"	6 40 "	+17.93	−508.8
"	6 43 "	+17.93	−507.6
"	8 20 "	+18.04	−518.8
"	8 23 "	+18.04	−518 0
"	8 30 "	+18.10	−514.6
"	8 33 "	+18.10	−515.1

SERIES II. — Continued.

Date.	Time.	Y 61	$S - T^{b_1}$	Date.	Time.	Y 61	$S - T^{b_1}$
1883.	h. m.	°	div.	1883.	h. m.	°	div.
May 4	8 40 P.M.	+18.18	—521.0	May 7	5 34 A.M.	+ 8.00	—193.3
“	8 43 “	+18.18	—519.7	“	6 50 “	+29.25	—884.4
“	2 55 P.M.	+20.05	—582.8	“	6 53 “	+29.25	—879.7
“	2 59 “	+20.05	—580.8	“	7 0 “	+29.14	—879.3
				“	7 3 “	+29.14	—876.3
May 6	9 0 A.M.	+16.44	—465.6				
“	9 3 “	+16.44	—466.1				
				May 8	5 25 A.M.	+12.82	—359.3
May 7	5 20 A.M.	+ 7.90	—197.3	“	5 30 “	+12.82	—347.8
“	5 24 “	+ 7.95	—197.8	“	5 35 “	+12.82	—349.2
“	5 30 “	+ 7.98	—192.4	“	5 40 “	+12.82	—348.7

EQUATIONS OF CONDITION BETWEEN T AND S.

SERIES I.

$$S - T^{b_1} = a + (\tau - 0°)\, b$$

1883.	$S - T^{b_1}$		$(\tau - 0°)$	a	Δa	Δa
Feb. 7	+ 17.6 div.	= a	+ 1.76 b	+74.5	—0.5 div.	—0.2 μ
“ 7	— 52.3 div.	= a	+ 3.83 b	+71.6	—3.4 div.	—1.7 μ
“ 7	—172.4 div.	= a	+ 7.60 b	+73.4	—1.6 div.	—0.8 μ
“ 8	+218.0 div.	= a	— 4.30 b	+78.9	+3.9 div.	+1.9 μ
“ 8	+ 20.4 div.	= a	+ 1.46 b	+67.6	—7.4 div.	—3.7 μ
“ 9	+221.4 div.	= a	— 4.54 b	+75.1	+0.1 div.	+0.0 μ
“ 11	—360.1 div.	= a	+13.47 b	+75.4	+0.4 div.	+0.2 μ
“ 12	+ 20.4 div.	= a	+ 1.78 b	+77.9	+2.9 div.	+1.4 μ
“ 12	+169.0 div.	= a	— 2.96 b	+73.3	—1.7 div.	—0.8 μ
“ 12	+ 98.3 div.	= a	— 0.79 b	+72.8	—2.2 div.	—1.1 μ
“ 13	+ 21.4 div.	= a	+ 1.69 b	+76.0	—1.0 div.	—0.5 μ
“ 13	+ 70.7 div.	= a	+ 0.12 b	+74.6	—0.4 div.	—0.2 μ
“ 13	— 26.4 div.	= a	+ 3.26 b	+79.0	+4.0 div.	+2.0 μ
“ 14	+280.6 div.	= a	— 6.50 b	+70.4	—4.6 div.	—2.3 μ
“ 15	—116.9 div.	= a	+ 5.82 b	+71.3	—3.7 div.	—1.8 μ
“ 16	+ 49.6 div.	= a	+ 0.78 b	+74.8	—0.2 div.	—0.1 μ
“ 18	—849.2 div.	= a	+28.40 b	+69.1	—5.9 div.	—2.9 μ
“ 19	—719.5 div.	= a	+24.53 b	+73.8	—1.2 div.	—0.6 μ
“ 20	+132.9 div.	= a	— 1.92 b	+70.8	—4.2 div.	—2.1 μ
“ 25	— 18.9 div.	= a	+ 2.96 b	+76.8	+1.8 div.	+0.9 μ
“ 25	—167.1 div.	= a	+ 7.58 b	+78.0	+3.0 div.	+1.5 μ
“ 25	—186.8 div.	= a	+ 8.31 b	+81.9	+6.9 div.	+3.4 μ
“ 26	—645.2 div.	= a	+22.37 b	+78.0	+3.0 div.	+1.5 μ
“ 27	+380.6 div.	= a	— 9.59 b	+70.5	—4.5 div.	—2.3 μ
“ 27	+293.9 div.	= a	— 6.71 b	+76.9	+1.9 div.	+0.9 μ

1883.	$S - T^{b_1}$			$(\tau - 0^\circ)$	a	Δa	Δa
Feb. 27	— 18.8 div.	=	a	+ 2.91 b	+75.3	+0.3 div.	+0.1 μ
" 28	+189.8 div.	=	a	— 3.47 b	+77.6	+2.6 div.	+1.3 μ
" 28	+ 83.9 div.	=	a	— 0.22 b	+76.8	+1.8 div.	—0.9 μ

Normal Equations.

$$-1065.1 = 28\,a + 97.63\,b \qquad b = -32.34$$

$$-76975.0 = +97.63\,a + 260.67\,b \qquad a = +75.0$$

EQUATIONS OF CONDITION BETWEEN T AND S.

Series II.

1883.	$S - T^{b_1}$			$(\tau - 0^\circ)$	a	Δa	Δa
Feb. 28	+ 86.3 div.	=	a	— 0.71 b	+63.5	+2.2 div.	+1.1 μ
Mar. 1	— 54.8 div.	=	a	+ 3.64 b	+62.1	+0.8 div.	+0.4 μ
" 3	—562.4 div.	=	a	+19.33 b	+58.5	—2.5 div.	—1.3 μ
" 4	+385.0 div.	=	a	—10.05 b	+62.2	+0.9 div.	+0.4 μ
" 4	+ 70.4 div.	=	a	— 0.35 b	+59.2	—2.1 div.	—1.0 μ
" 5	+207.4 div.	=	a	— 4.38 b	+66.7	+5.4 div.	+2.7 μ
" 5	+103.5 div.	=	a	— 1.18 b	+65.6	+4.3 div.	+2.2 μ
" 6	+308.2 div.	=	a	— 7.72 b	+60.3	—1.0 div.	—0.5 μ
April 15	—560.8 div.	=	a	+19.41 b	+62.7	+1.4 div.	+0.7 μ
" 17	—332.7 div.	=	a	+12.25 b	+60.8	—0.5 div.	—0.3 μ
" 18	—230.6 div.	=	a	+ 9.14 b	+63.0	+1.7 div.	+0.8 μ
" 19	—216.2 div.	=	a	+ 8.64 b	+61.3	+0.0 div.	+0.0 μ
" 20	—516.8 div.	=	a	+17.96 b	+60.1	—1.2 div.	—0.6 μ
" 22	— 86.9 div.	=	a	+ 4.57 b	+59.9	—1.4 div.	—0.7 μ
" 23	—130.8 div.	=	a	+ 5.97 b	+60.9	—0.4 div.	—0.2 μ
" 24	—133.9 div.	=	a	+ 6.02 b	+59.5	—1.8 div.	—0.9 μ
" 24	—122.0 div.	=	a	+ 5.67 b	+60.1	—1.2 div.	—0.6 μ
" 24	—752.0 div.	=	a	+25.40 b	+64.0	+2.7 div.	+1.3 μ
" 24	—593.9 div.	=	a	+20.47 b	+63.6	+2.3 div.	+1.2 μ
" 25	— 20.6 div.	=	a	+ 2.47 b	+58.7	—2.6 div.	—1.3 μ
" 25	— 60.9 div.	=	a	+ 3.75 b	+59.5	—1.8 div.	—0.9 μ
" 25	—586.8 div.	=	a	+20.04 b	+57.0	—4.3 div.	—2.1 μ
" 26	— 14.2 div.	=	a	+ 2.24 b	+57.8	—3.5 div.	—1.7 μ
" 26	—622.4 div.	=	a	+21.26 b	+60.6	—0.7 div.	—0.4 μ
" 26	—776.7 div.	=	a	+26.07 b	+60.7	—0.6 div.	—0.3 μ
" 27	—117.4 div.	=	a	+ 5.59 b	+62.2	+0.9 div.	+0.5 μ
" 27	—229.6 div.	=	a	+ 9.02 b	+60.1	—1.2 div.	—0.6 μ
" 27	—465.7 div.	=	a	+16.37 b	+60 1	—1.2 div.	—0.6 μ
" 28	—534.1 div.	=	a	+18.54 b	+61.5	+0.2 div.	+0.1 μ
" 29	—430.6 div.	=	a	+15.35 b	+62.5	+1.2 div.	+0.6 μ

1883.	$S - T^{b_1}$			$(\tau - 0°)$	a	Δa	Δa
April 29	—453.9 div.	=	a	+16.01 b	+60.4	—0.9 div.	—0.4 μ
" 29	—826.8 div.	=	a	+27.60 b	+59.7	—1.6 div.	—0.8 μ
" 30	— 53.2 div.	=	a	+ 3.57 b	+61.5	+0.2 div.	+0.1 μ
" 30	—449.0 div.	=	a	+15.88 b	+61.2	—0.1 div.	+0.0 μ
" 30	—510.1 div.	=	a	+17.76 b	+60.4	—0.9 div.	—0.4 μ
May 1	—127.7 div.	=	a	+ 5.81 b	+58.9	—2.4 div.	—1.2 μ
" 1	—505.0 div.	=	a	+17.68 b	+63.0	+1.7 div.	+0.9 μ
" 1	—472.9 div.	=	a	+16.56 b	+59.1	—2.2 div.	—1.1 μ
" 2	—219.3 div.	=	a	+ 8.72 b	+60.8	—0.5 div.	—0.3 μ
" 4	—512.4 div.	=	a	+18.07 b	+68.0	+6.7 div.	+3.3 μ
" 4	—517.8 div.	=	a	+18.16 b	+65.6	+4.3 div.	+2.2 μ
" 4	—581.8 div.	=	a	+20.12 b	+64.5	+3.2 div.	+1.6 μ
" 6	—465.8 div.	=	a	+16.47 b	+63.3	+2.0 div.	+2.0 μ
" 7	—195.2 div.	=	a	+ 7.92 b	+59.2	—2.1 div.	—1.0 μ
" 7	—879.9 div.	=	a	+29.34 b	+62.5	+1.2 div.	+0.6 μ
" 8	—351.3 div.	=	a	+12.84 b	+61.2	—0.1 div.	—0.1 μ

Normal Equations.

$$-14114.1 = 46\,a + 527.29\,b \qquad b = -32.12$$

$$-288794.2 = 527.29\,a + 9999.52\,b \qquad a = +61.3$$

Combination of Results.

		Weight.
Series I.	$b = -32.34$ div.	1
Series II.	$b = -32.12$ div.	3

Hence:—

$b = -32.18$ div. $= -16.22\,\mu$ for each degree Centigrade.

COMPARISON OF LINE-METER *C. S.* WITH END-METER *S* IN MELTING ICE WITH ONE-INCH OBJECTIVE.

(1 div. = .504 μ.)

SERIES I.

Date.	Y 61	$S - C.S.$	Date.	Y 61	$S - C.S.$
1883.	°	div.	1883.	°	div.
Feb. 11	+13.00	+ 42.7	Feb. 13	+ 4.77	+339.5
"	+13.00	+ 54.0	"	+ 4.75	+341.5
"	+13.00	+ 61.2	"	+ 4.72	+341.4
"	+13.00	+ 55.2	"	— 7 92	+778.0
			"	— 7.92	+769.0
Feb. 12	— 0.14	+501.2	"	— 7.98	+767.8
"	— 0.14	+503.3	"	— 7.94	+775.5
"	— 1.28	+541.1			
"	— 1.16	+533.6	Feb. 14	— 4.98	+664.3
"	— 1.16	+545.9	"	— 5.02	+683.6
"	— 1.06	+544.3			
"	— 1.28	+549.4	Feb. 15	+ 6.42	+283.9

SERIES I. — Continued.

Date.	*Y* 61	*S — C.S.*	Date.	*Y* 61	*S—C.S.*
1883.	°	div.	1883.	°	div.
Feb. 15	+ 6.42	+274.8	Feb. 25	+ 8.28	+220.8
"	+ 6.26	+280.2	"	+ 8.30	+215.9
"	+ 6.26	+275.3	"	+ 8.34	+218.5
"	+ 5.92	+283.8	"	+ 8.34	+215.5
"	+ 5.95	+291.9	"	+ 8.34	+218.7
Feb. 16	— 1.46	+537.1	Feb. 26	+22.96	—292.9
"	— 1.48	+539.4	"	+22.94	—295.4
"	— 1.50	+536.2	"	+23.07	—305.3
"	— 1.49	+536.6	"	+23.07	—299.0
"	— 1.48	+540.6	"	+21.88	—268.1
"	— 1.48	+541.7	"	+21.86	—270.0
"	— 1.48	+542.7	"	+21.86	—268.6
Feb. 18	+27.45	—464.4	Feb. 27	+ 0.55	+468.1
"	+27.36	—467.9	"	+ 0.60	+467.0
"	+27.48	—470.5	"	+ 0.70	+464.8
"	+27.66	—461 8	"	+ 0.80	+462.3
"	+27.66	—471.2	"	+ 0.74	+468.6
"	+27.76	—472.8	"	—10.10	+835.4
			"	—10.08	+835.2
Feb. 19	+27.22	—456.1	"	—10.14	+837.5
			"	—10.14	+842.5
Feb. 20	— 3 11	+590.1			
"	— 2.99	+596 4	Feb. 28	— 2 66	+594.3
			"	— 2.66	+590.9
Feb. 25	+ 1.74	+439.1	"	— 1.10	+542.8
"	+ 1.76	+443.8	"	— 1.10	+534.8
"	+ 1.78	+448 1	"	— 0.11	+507.7
"	+ 1.80	+443.4	"	— 0.11	+502.2

SERIES II.

Date.	Time.	*Y* 61	*S—C.S.*	Date.	Time.	*Y* 61	*S—C.S*
1833.	h. m.	°	div.	1883.	h. m	°	div.
Feb. 28	7 3 A.M	— 0.84	+513.4	Mar. 1	10 30 A.M.	+ 5.97	+272.0
"	7 9 "	— 0.84	+517.6	"	10 35 "	+ 5 98	+274.6
"	7 12 "	— 0.79	+514.5	"	11 0 "	+ 5.44	+298.7
"	7 15 "	— 0.81	+511.7	"	11 10 "	+ 5.44	+298.5
"	8 0 "	— 2.18	+558.8				
"	8 3 "	— 2.18	+555.4	Mar. 3	7 10 A.M.	+19.24	—192.4
"	8 15 "	— 2.60	+577.0	"	7 30 "	+19.22	—190.8
"	8 20 "	— 2.64	+573.0	"	7 40 "	+19.15	—178.9
"	10 5 "	— 3.86	+616.9	"	7 55 "	+19.15	—181.0
"	10 8 "	— 3.88	+612.6				
"	3 20 P.M.	+ 3.14	+381 1	Mar. 4	7 50 A.M.	—10.60	+836.2
"	3 25 "	+ 3.14	+374.5	"	7 55 "	—10.57	+836.3
"	3 40 "	+ 3.30	+382.7	"	8 0 "	—10.48	+834.4
"	3 45 "	+ 3.12	+378 6	"	8 5 "	—10.45	+833 0
"	3 50 "	+ 3.16	+376.9	"	8 15 "	—10.40	+834.7
"	3 55 "	+ 3.16	+376.2	"	8 20 "	—10.40	+832.1

SERIES II. — Continued.

Date.	Time.	*Y* 61	*S—C.S.*
1883.	h. m.	°	div.
Mar. 4	8 30 A.M.	—10.10	+829.5
"	8 35 "	—10.08	+825.3
"	8 20 "	— 9.34	+807.9
"	8 25 "	— 9.30	+802.7
"	9 0 "	— 9.68	+816.4
"	9 10 "	— 9.64	+816.4
"	9 30 "	— 9.11	+798.1
"	9 40 "	— 9.09	+794.9
"	10 25 "	— 8 34	+768.8
"	10 30 "	— 8.20	+760.4
"	12 30 P.M.	— 4.56	+648.9
"	12 33 "	— 4.50	+643.2
"	4 40 "	— 0.92	+524.6
"	4 43 "	— 0.90	+519.4
"	5 10 "	— 0.74	+507.6
"	5 13 "	— 0.78	+509.6
"	5 18 "	— 0.76	+511.3
"	5 20 "	— 0.94	+517.1
"	5 22 "	— 0.96	+511.7
"	5 25 "	— 0.76	+510.0
"	5 30 "	— 1.10	+520.1
"	5 33 "	— 1.16	+519.5
"	5 40 "	— 1.00	+518.7
"	5 43 "	— 1.00	+518.3
Mar. 5	7 20 A.M.	—12.80	+911.8
"	7 23 "	—12.80	+902.3
"	8 15 "	—12.70	+916.8
"	8 20 "	—12.70	+908.1
Apr. 18	6 0 A.M.	+ 8.87	+182.9
"	6 5 "	+ 8.87	+179.9
Apr. 19	7 0 A.M.	+ 7.04	+234.1
"	7 10 "	+ 7.00	+240.7
"	7 30 "	+ 6.62	+256.7
"	7 40 "	+ 6.42	+260.3
"	7 45 "	+ 6.56	+253.6
"	7 50 "	+ 6.84	+252.6
"	5 15 P.M.	+23 14	—323.5
"	5 20 "	+23.00	—313.6
"	5 25 "	+22.90	—310.1
"	5 30 "	+22 70	—303 3
"	5 35 "	+22.54	—301.4
"	5 45 "	+22.43	—290.2
Apr. 20	6 20 A.M.	+17.74	—141.0
"	6 30 "	+17.74	—123.9
Apr. 21	6 30 A.M.	+16.75	—100.9
Apr. 22	7 0 A.M.	+ 3 96	+339.5
"	7 3 "	+ 4.00	+345.3
"	7 10 "	+ 4.00	+344.5
"	7 28 "	+ 4.26	+336.6
1883.	h. m.	°	div.
Apr. 22	7 30 A.M.	+ 4.36	+337.5
"	6 0 P.M.	+24.28	—371.1
"	6 20 "	+24.40	—370.1
"	6 30 "	+24.40	—367.0
"	6 40 "	+24.40	—365.0
Apr. 23	6 30 A.M.	+ 5.88	—284.1
"	6 35 "	+ 5.88	—282.7
"	6 45 "	+ 5.90	—287.9
"	6 50 "	+ 5.90	—287.3
"	6 55 "	+ 5.90	—284.8
"	7 0 "	+ 5.88	—281.3
"	7 10 "	+ 5.74	—286.0
"	7 12 "	+ 5.74	—282.1
"	8 45 "	+ 5.88	—282.0
"	8 50 "	+ 5.88	—281.3
"	8 55 "	+ 5.88	—286.9
"	9 0 "	+ 5.88	—281.5
Apr. 24	5 40 A.M.	+ 5.90	+284.9
"	5 45 "	+ 5.84	+288.4
"	5 48 "	+ 5.84	+286.0
"	6 0 "	+ 5.78	+281.8
"	6 3 "	+ 5.78	+281.7
"	6 5 "	+ 5.84	+287.9
"	6 8 "	+ 5.84	+286.7
"	6 15 "	+ 5.84	+285.8
"	6 18 "	+ 5.84	+284.9
"	9 25 "	+20.28	—216.7
"	9 28 "	+20.20	—217.1
Apr. 25	5 45 A.M.	+ 2.25	+408.5
"	5 48 "	+ 2.25	+407.3
"	6 0 "	+ 2.25	+405.6
"	6 5 "	+ 2.25	+411.5
"	6 10 "	+ 2.25	+407.6
"	6 13 "	+ 2.25	+408.2
"	6 15 "	+ 2.25	+408.1
"	6 17 "	+ 2 25	+406.6
"	4 25 P.M.	+20 32	—216.3
"	4 27 "	+20.32	—219.9
"	9 0 "	+20.74	—236.4
"	9 5 "	+20.74	—233.8
Apr. 26	5 40 A.M.	+ 1.60	+425.3
"	5 45 "	+ 1.60	+433.0
"	5 50 "	+ 1.50	+430.2
"	5 53 "	+ 1.50	+428.3
"	5 55 "	+ 1.60	+427.4
"	6 0 "	+ 1.52	+427.3
"	6 3 "	+ 1.52	+422.2
"	6 18 "	+ 1.45	+424.6
"	6 22 "	+ 1.55	+420.8
"	6 25 "	+ 1.60	+423.5
"	6 35 "	+ 1.60	+423.7

SERIES II. — Continued.

Date.	Time.	Y 61	S—C.S.
1883.	h. m.	°	div.
Apr. 26	6 38 A.M.	+ 1.65	+420.2
“	8 50 P.M.	+25.46	—395.1
“	8 53 “	+25.46	—394.0
“	8 57 “	+25.44	—399.0
“	8 59 “	+25.44	—396.0
Apr. 27	5 50 A.M.	+ 4.82	+322.5
“	5 55 “	+ 4.82	+322.5
“	6 5 “	+ 4.90	+322.0
“	6 8 “	+ 4.90	+317.3
“	6 12 “	+ 5.07	+314.4
“	6 15 “	+ 5.12	+311.0
“	6 25 “	+ 5.30	+294.2
“	6 28 “	+ 5.30	+300.8
“	4 0 P.M.	+25.45	—400.4
“	4 10 “	+25.45	—399.8
Apr. 28	7 50 A.M.	+18.66	—166.4
“	7 52 “	+18.66	—164.3
“	8 0 “	+18.66	—161.5
“	8 3 “	+18.66	—162.5
Apr. 29	1 55 P.M.	+ 8.05	+208.1
“	1 58 “	+ 8.05	+211.1
“	2 10 “	+ 8.12	+207.5
“	2 13 “	+ 8.12	+208.1
“	2 17 “	+ 8.12	+205.7
“	2 19 “	+ 8.12	+204.3
“	2 25 “	+ 8.20	+205.7
“	2 27 “	+ 8.20	+204.7
“	7 45 “	+27.26	—473.9
“	8 0 “	+27.16	—466.9
“	8 20 “	+27.00	—458.6
“	8 50 “	+27.16	—462.0
Apr. 30	5 26 A.M.	+ 1.72	+413.9
“	5 29 “	+ 1.72	+406.8
“	5 44 “	+ 1.82	+403.6
“	5 48 “	+ 1.82	+400.0
“	5 55 “	+ 2.02	+396.2
“	6 0 “	+ 2.10	+402.9
“	6 10 “	+ 2.15	+398.8
“	6 20 “	+ 2.24	+392.5
May 1	5 15 A.M.	+ 5.13	+291.0
“	5 18 “	+ 5.13	+286.7
“	5 25 “	+ 5.13	+290.9
“	5 27 “	+ 5.13	+287.1
“	5 30 “	+ 5.20	+296.7
“	5 33 “	+ 5.20	+290.5
“	5 40 “	+ 5.26	+291.0
“	5 43 “	+ 5.26	+289.2
“	7 38 P.M.	+16.67	— 88.0
“	7 41 “	+16.67	— 89.5
“	7 50 “	+16.63	— 90.3
1883.	h. m.	°	div.
May 1	7 53 P.M.	+16.63	— 87.4
May 2	5 30 A.M.	+ 7.48	+216.9
“	5 33 “	+ 7.52	+211.4
“	5 36 “	+ 7.55	+216.3
“	5 39 “	+ 7.60	+214.3
“	5 40 “	+ 7.60	+214.8
“	5 48 “	+ 7.68	+214.6
“	5 51 “	+ 7.68	+213.0
“	12 50 P.M.	+18.02	—153.3
“	12 55 “	+18.02	—148.8
“	12 58 “	+18.02	—147.9
“	1 8 “	+18.07	—144.9
“	1 11 “	+18.07	—145.0
“	5 30 “	+18.85	—172.5
“	5 40 “	+18.85	—172.9
“	5 50 “	+18.93	—183.6
“	5 54 “	+18.98	—182.4
“	6 15 “	+19.04	—173.4
“	8 40 “	+19.06	—184.2
“	8 52 “	+19.06	—181.9
“	9 0 “	+19.12	—170.4
“	9 12 “	+19.12	—171.3
May 3	6 5 A.M.	+18.66	—171.4
“	6 8 “	+18.66	—170.1
“	6 15 “	+18.50	—162.8
“	6 17 “	+18.50	—165.8
“	6 25 “	+18.40	—157.5
“	6 28 “	+18.40	—161.0
“	6 45 “	+18.14	—152.2
“	6 48 “	+18.14	—149.9
“	8 30 “	+17.88	—137.4
“	8 33 “	+17.88	—137.4
“	8 40 “	+17.86	—137.0
“	8 43 “	+17.86	—137.5
“	1 0 P.M.	+18.16	—143.3
“	1 3 “	+18.16	—143.8
“	1 15 “	+18.16	—139.6
“	1 18 “	+18.16	—141.8
May 4	5 40 A.M.	+18.46	—164.8
“	5 43 “	+18.46	—158.8
“	5 50 “	+18.35	—158.2
“	5 53 “	+18.35	—159.0
“	6 0 “	+18.25	—153.5
“	6 3 “	+18.25	—152.0
“	6 10 “	+18.16	—146.3
“	6 13 “	+18.16	—146.3
May 6	7 0 A.M.	+17.42	—124.1
“	7 3 “	+17.42	—123.0
“	9 12 “	+16.47	— 77.1
“	9 15 “	+16.47	— 78.2
“	9 45 “	+16.47	— 80.8

Series II. — Continued.

Date.	Time.	*Y* 61	*S*—*C.S.*	Date.	Time.	*Y* 61	*S*—*C.S.*
1883.	h. m.	°	div.	1883.	h. m.	°	div.
May 6	9 48 A.M.	+16.47	—84.6	May 7	5 45 A.M.	+ 7.80	+210.1
"	12 10 P.M.	+16.67	—93.6	"	5 48 "	+ 7.80	+213.7
"	12 13 "	+16.67	—94.9	"	6 10 "	+ 8 08	+200.0
"	12 20 "	+16.67	—91.1	"	6 12 "	+ 8.08	+198.8
"	12 23 "	+16.67	—91.2	"	6 35 P.M.	+29.64	—540.0
				"	6 37 "	+29.64	—544.1

EQUATIONS OF CONDITION BETWEEN METERS *C.S.* AND *S.*

Series I.

1883.	*S* — *C.S*		(τ — 0°)	*a*	Δ*a*	Δ*a*
Feb. 11	+ 53.3 div.	=	*a* +13.02 *b*	+500.1	+ 0.9 div.	+0.5 μ
" 12	+502.2 div.	=	*a* — 0.14 *b*	+497.3	— 1.9 div.	—1.0 μ
" 12	+542.9 div.	=	*a* — 1.15 *b*	+502.9	+ 3.7 div.	+1.8 μ
" 13	+340.8 div.	=	*a* + 4.69 *b*	+504.1	+ 4.9 div.	+2.4 μ
" 13	+772.6 div.	=	*a* — 7.76 *b*	+502.4	+ 3.2 div.	+1.6 μ
" 14	+673.9 div.	=	*a* — 4.87 *b*	+504.3	+ 5.1 div.	+2.6 μ
" 15	+281.6 div.	=	*a* + 6.14 *b*	+495.4	— 3.8 div.	—1.9 μ
" 16	+539.2 div.	=	*a* — 1.44 *b*	+487.8	—11.4 div.	—5.7 μ
" 18	—467.6 div.	=	*a* +27.56 *b*	+492.0	— 7.2 div.	—3.6 μ
" 18	—468.6 div.	=	*a* +27.84 *b*	+500.8	+ 1.6 div.	+0.8 μ
" 19	—456.1 div.	=	*a* +27.36 *b*	+496.6	— 2.6 div.	—1.3 μ
" 20	+593.3 div.	=	*a* — 2.96 *b*	+490.2	— 9.0 div.	—4.5 μ
" 25	+443.6 div.	=	*a* + 1.75 *b*	+504.5	+ 5.3 div.	+2.6 μ
" 25	+217.9 div.	=	*a* + 8.28 *b*	+506.1	+ 6.9 div.	+3.5 μ
" 26	—298.2 div.	=	*a* +23.11 *b*	+506.5	+ 7.3 div.	+3.6 μ
" 26	—268.9 div.	=	*a* +21.96 *b*	+495.7	— 3.5 div.	—1.7 μ
" 27	+466.2 div.	=	*a* + 0.67 *b*	+489.5	— 9.7 div.	—4.8 μ
" 27	+837.6 div.	=	*a* — 9.79 *b*	+496.7	— 2.5 div.	—1.3 μ
" 28	+592.6 div.	=	*a* — 2.58 *b*	+502.8	+ 3.6 div.	+1.8 μ
" 28	+538.8 div.	=	*a* — 1.07 *b*	+501.5	+ 2.3 div.	+1.1 μ
" 28	+505.0 div.	=	*a* — 0.11 *b*	+501.2	+ 2.0 div.	+1.0 μ

Normal Equations.

$$+5942.1 = 21\,a + 130.51\,b \qquad b = -34.82$$

$$-67160.4 = +130.51\,a + 3800.56\,b \qquad a = +499.2$$

EQUATIONS OF CONDITION BETWEEN METERS *S* AND *C.S.*

SERIES II.

1883.	$S - C.S$		$(\tau - 0^\circ)$	a	Δa	Δa
Feb. 28	+514.3 div.	=	$a - 0.80\,b$	+486.5	+ 1.4 div.	+0.7 μ
“ 28	+566.0 div.	=	$a - 2.33\,b$	+485.0	− 0.1 div.	−0.1 μ
“ 28	+614.7 div.	=	$a - 3.76\,b$	+484.0	− 1.1 div.	−0.5 μ
“ 28	+378.3 div.	=	$a + 3.13\,b$	+487.2	+ 2.1 div.	+1.0 μ
Mar. 1	+286.0 div.	=	$a + 5.65\,b$	+482.4	− 2.7 div.	−1.4 μ
“ 3	−185.8 div.	=	$a + 19.27\,b$	+484.0	− 1.1 div.	−0.5 μ
“ 4	+832.7 div.	=	$a - 10.03\,b$	+484.0	− 1.1 div.	−0.6 μ
“ 4	+806.1 div.	=	$a - 9.09\,b$	+490.0	+ 4.9 div.	+2.4 μ
“ 4	+764.6 div.	=	$a - 8.06\,b$	+484.4	− 0.7 div.	−0.3 μ
“ 4	+646.0 div.	=	$a - 4.40\,b$	+493.6	+ 8.5 div.	+4.2 μ
“ 4	+515.7 div.	=	$a - 0.89\,b$	+484.8	− 0.3 div.	−0.1 μ
“ 5	+909.8 div.	=	$a - 12.27\,b$	+483.2	− 1.9 div.	−0.9 μ
April 18	+181.4 div.	=	$a + 8.85\,b$	+489.1	+ 4.0 div.	+2.0 μ
“ 19	+249.7 div.	=	$a + 6.70\,b$	+482.7	− 2.4 div.	−1.2 μ
“ 19	−307.0 div.	=	$a + 22.88\,b$	+488.5	+ 3.4 div.	+1.7 μ
“ 20	−132.4 div.	=	$a + 17.79\,b$	+488.6	+ 3.5 div.	+1.7 μ
“ 21	−100.9 div.	=	$a + 16.79\,b$	+482.9	− 2.2 div.	−1.1 μ
“ 22	+340.7 div.	=	$a + 4.07\,b$	+482.2	− 2.9 div.	−1.5 μ
“ 22	−368.3 div.	=	$a + 24.48\,b$	+482.9	− 2.2 div.	−1.1 μ
“ 23	+284.5 div.	=	$a + 5.79\,b$	+485.8	+ 0.7 div.	+0.4 μ
“ 23	+282.9 div.	=	$a + 5.88\,b$	+487.3	+ 2.2 div.	+1.1 μ
“ 24	+285.3 div.	=	$a + 5.77\,b$	+485.9	+ 0.8 div.	+0.4 μ
“ 24	−216.9 div.	=	$a + 20.31\,b$	+489.3	+ 4.2 div.	+2.1 μ
“ 25	+407.9 div.	=	$a + 2.23\,b$	+485.4	+ 0.3 div.	+0.1 μ
“ 25	−218.1 div.	=	$a + 20.39\,b$	+490.8	+ 5.7 div.	+2.8 μ
“ 25	−235.1 div.	=	$a + 20.82\,b$	+488.8	+ 3.7 div.	+1.8 μ
“ 26	+425.5 div.	=	$a + 1.54\,b$	+479.0	− 6.1 div.	−3.0 μ
“ 26	−396.0 div.	=	$a + 25.57\,b$	+493.1	+ 8.0 div.	+4.0 μ
“ 27	+313.1 div.	=	$a + 4.97\,b$	+485.9	+ 0.8 div.	+0.4 μ
“ 27	−400.1 div.	=	$a + 25.57\,b$	+489.0	+ 3.9 div.	+2.0 μ
“ 28	−163.7 div.	=	$a + 18.71\,b$	+487.8	+ 2.7 div.	+1.4 μ
“ 29	+206.9 div.	=	$a + 8.08\,b$	+487.8	+ 2.7 div.	+1.3 μ
“ 29	−465.4 div.	=	$a + 27.28\,b$	+483.1	− 2.0 div.	−1.0 μ
“ 30	+401.8 div.	=	$a + 1.93\,b$	+468.9	−16.2 div.	−8.1 μ
May 1	+290.4 div.	=	$a + 5.12\,b$	+468.4	−16.7 div.	−8.4 μ
“ 1	− 88.8 div.	=	$a + 16.69\,b$	+491.5	+ 6.4 div.	+3.2 μ
“ 2	+214.5 div.	=	$a + 7.55\,b$	+477.0	− 8.1 div.	−4.1 μ
“ 2	−148.0 div.	=	$a + 18.09\,b$	+481.0	− 4.1 div.	−2.0 μ
“ 2	−177.0 div.	=	$a + 18.99\,b$	+483.3	− 1.8 div.	−0.9 μ
“ 2	−176.9 div.	=	$a + 19.15\,b$	+488.9	+ 3.8 div.	+1.9 μ

1883.		$S - C.S.$			$(\tau - 0^{\circ})$	a	Δa	Δa
May	3	—161.3 div.	=	a	+18.47 b	+480.9	—4.2 div.	—2.1 μ
"	3	—137.3 div.	=	a	+17.82 b	+482.3	—2.8 div.	—1.4 μ
"	3	—142.1 div.	=	a	+18.21 b	+491.1	+6.0 div.	+3.0 μ
"	4	—154.9 div.	=	a	+18.35 b	+483.1	—2.0 div.	—1.0 μ
"	6	— 80.2 div.	=	a	+16.50 b	+493.5	+8.4 div.	+4.2 μ
"	6	—123.6 div.	=	a	+17.46 b	+483.5	—1.6 div.	—0.8 μ
"	6	— 92.7 div.	=	a	+16.71 b	+488.3	+3.2 div.	+1.6 μ
"	7	+205.6 div.	=	a	+ 7.90 b	+480.2	—4.9 div.	—2.5 μ
"	7	—542.0 div.	=	a	+29.80 b	+494.2	+9.1 div.	+4.5 μ

Normal Equations.

$$+5709.7 = 49a + 519.64b \qquad b = -34.77$$

$$-134583.1 = +519.64a + 11121.80b \qquad a = +485.1$$

Combining results we have, giving the value of b in the first series a weight of 1, and in the second series a weight of 3,

$$b = -34.78 \text{ div.} = -17.53 \mu.$$

COMPARISON OF LINE-METER $R_2^{a_2}$ WITH END-METER S IN MELTING ICE WITH ONE-INCH OBJECTIVE.

(1 div. = 504 μ.)

SERIES I.

Date.	Y 61	$R_2^{a_2} - S$	Date.	Y 61	$R_2^{a_2} - S$
1883.	°	div.	1883.	°	div.
Feb. 11	+12.74	+ 14.2	Feb. 13	— 7.57	+718.4
"	+13.14	+ 9.8	Feb. 14	+ 1.80	+390.8
"	+13.10	+ 6.0	"	+ 1.86	+398.7
Feb. 12	+ 0.54	+433.2	Feb. 15	+ 5.10	+282.5
"	+ 0.64	+431.2	"	+ 4.98	+284.0
"	— 1.13	+495.4	"	+ 4.85	+283.0
"	— 1.40	+497.8	"	+ 4.84	+288.0
"	— 1.30	+489.0	Feb. 16	— 2.32	+518.3
"	— 1.58	+498.5	"	— 2.32	+520.1
Feb. 13	+ 1.40	+488.0	"	— 2.37	+518.3
"	+ 1.50	+489.6	"	— 2.40	+517.7
"	+ 1.68	+489.3	"	+ 3.68	+320.1
"	+ 1.57	+491.6	"	+ 3.69	+324.7
"	+ 1.57	+486.9	"	+ 3.72	+320.8
"	— 6.80	+685.0	Feb. 18	+28.11	+532.9
"	— 7.10	+681.8	"	+28.14	+534.1
"	— 7.26	+702.0	"	+28.28	+541.9
"	— 7.17	+698.4	"	+29.06	—545.5
"	— 7.38	+710.8	"	+29.08	—552.3
"	— 7.68	+711.8			

SERIES I. — Continued.

Date.	Y 61	$R_2^{a_2} - S$	Date.	Y 61	$R_2^{a_2} - S$
1883.	°	div.	1883.	°	div.
Feb. 18	+28.56	—555.8	Feb. 26	+21.00	—269.0
"	+28.56	—541.1			
"	+24.06	—403.4	Feb. 27	+ 3.22	+331.5
"	+24.04	—397.0	"	+ 3.20	+343.5
"	+24.05	—395.6	"	+ 3.20	+345.5
			"	+ 2.10	+368.9
Feb. 25	+ 8.44	+169.8	"	+ 2.12	+370.7
"	+ 8.54	+168.1	"	+ 2.00	+379.1
"	+ 8.54	+167.9	"	+ 2.00	+380.7
			"	+ 2.10	+368.9
Feb. 26	+20.36	—259.2	"	+ 2.10	+370.7
"	+20.40	—268.0			
"	+20.40	—268.0	Feb. 28	— 4.47	+605.3
"	+20.34	—249.3	"	— 4.47	+598.8
"	+20.90	—262.7	"	— 4.47	+599.7
"	+20.90	—258.6	"	— 4.47	+595.1
"	+21.00	—263.7	"	— 4.47	+594.9

SERIES II.

Date.	Y 61	$R_2^{a_2} - S$	Date.	Y 61	$R_2^{a_2} - S$
1883.	°	div.	1883.	°	div.
Mar. 1	+ 3.24	+324.3	Mar. 4	+19.88	—250.4
"	+ 3.24	+323.4	"	+19.88	—248.6
"	+ 3.30	+323.0	"	+19.88	—242.3
"	+ 3.30	+323.4	"	+19.88	
"	+ 3.34	+319.6			
"	+ 3.34	+319.7	Mar. 6	+16.46	—123.8
			"	+16.46	—125.2
Mar. 2	+ 4.42	+283.4	"	+16.46	—129.9
"	+ 4.44	+283.5	"	+16.46	—130.5
"	+ 4.44	+279.0	"	+16.54	—135.7
"	+ 4.44	+281.4	"	+16.54	—134.0
"	+ 4.54	+274.0			
"	+ 4.54	+270.6	Mar. 7	+ 8.10	+151.2
"	+ 4.72	+270.4	"	+ 8.20	+148.2
"	+ 4.72	+268.1	"	+ 8.40	+144.8
			"	+ 8.46	+141.8
Mar. 3	+19.18	—212.8	"	+29.92	—587.2
"	+19.18	—215.8	"	+29.92	—583.0
"	+19.18	—213.3	"	+29.92	—592.8
"	+19.18	—213.4	"	+29.92	—593.2
			"	+29.88	—592.6
Mar. 4	—11.40	+810.7	"	+29.88	—590.0
"	—11.35	+813.2	"	+29.98	—596.8
"	—11.35	+796.2	"	+29.98	—598.4
"	—11.45	+800.0	"	+29.98	—589.1
"	+18.00	—166.5	"	+29.98	—595.7
"	+18.00	—168.3	"	+29.98	—594.5
"	+18.00	—177.2			
"	+18.00	—172.0	Mar. 8	+12.90	— 18.4
"	+18.00	—172.7	"	+12.90	— 17.2
"	+18.00	—173.4	"	+12.90	— 10.5
"	+18.00	—174.2	"	+12.90	— 14.0
"	+19.72	—244.1	"	+12.90	— 16.3
"	+19.72	—241.4	"	+12.90	— 15.0

EQUATIONS OF CONDITION BETWEEN METERS $R_2^{a_2}$ AND S.

SERIES I.

1883.	$R_2^{a_2} - S$			$(\tau - 0^\circ)$	a	Δa	Δa
Feb. 11	+ 10.0 div.	=	a	+13.01 b	+460.7	+ 9.9 div.	+4.5 μ
" 12	+432 2 div.	=	a	+ 0.58 b	+452.3	+ 1.5 div.	+0.7 μ
" 12	+495.2 div.	=	a	— 1.31 b	+449.8	— 1.0 div.	—0.5 μ
" 13	+389.1 div.	=	a	+ 1.52 b	+441.8	— 9.0 div.	—4.5 μ
" 13	+701.2 div.	=	a	— 7.10 b	+455.3	+ 4.5 div.	+2.3 μ
" 14	+394.7 div.	=	a	+ 1.81 b	+457.4	+ 6.6 div.	+3.3 μ
" 15	+284.4 div.	=	a	+ 4.89 b	+453.8	+ 3.0 div.	+1.5 μ
" 16	+518.6 div.	=	a	— 2.28 b	+439.6	—11.2 div.	—5.6 μ
" 16	+321.9 div.	=	a	+ 3 65 b	+448.3	— 2.5 div.	—1.3 μ
" 18	—536.3 div.	=	a	+28.33 b	+445.1	— 5.7 div.	—2.8 μ
" 18	—548.7 div.	=	a	+28.97 b	+454.8	+ 4.0 div.	+2.0 μ
" 18	—398.3 div.	=	a	+24.16 b	+438.6	—12.2 div.	—6.1 μ
" 25	+168.6 div.	=	a	+ 8.48 b	+462.3	+11.5 div.	+5.7 μ
" 26	—261.1 div.	=	a	+20.46 b	+447.6	— 3.2 div.	—1.6 μ
" 26	—263.5 div.	=	a	+21.03 b	+465.0	+14.2 div.	+7.1 μ
" 27	+340.2 div.	=	a	+ 3.17 b	+450.0	— 0.8 div.	—0.4 μ
" 27	+373.2 div.	=	a	+ 2.05 b	+444.2	— 6.6 div.	—3.3 μ
" 28	+598.8 div.	=	a	— 4.35 b	+448.1	— 2.7 div.	—1.8 μ

Normal Equations.

$$+3020.2 = 18\,a + 147.07\,b \qquad b = -34.64$$
$$-53584.6 = 147.07\,a + 3461.25\,b \qquad a = +450.8$$

EQUATIONS OF CONDITION BETWEEN METERS $R_2^{a_2}$ AND S.

SERIES II.

1883.	$R_2^{a_2} - S$			$(\tau - 0^\circ)$	a	Δa	Δa
Mar. 1	+322.2 div.	=	a	+ 3.25 b	+432.4	+ 2.0 div.	+1.0 μ
" 2	+276.3 div.	=	a	+ 4.47 b	+427.9	— 2.5 div.	—1.2 μ
" 3	—213.8 div.	=	a	+19.24 b	+438.8	+ 8.4 div.	+4.2 μ
" 4	+805.0 div.	=	a	—10.97 b	+432.9	+ 2.5 div.	+1.2 μ
" 4	—172.0 div.	=	a	+18.05 b	+441.3	+10.9 div.	+5.5 μ
" 4	—242.7 div.	=	a	+19.78 b	+428.2	— 2.2 div.	—1.1 μ
" 4	—247.1 div.	=	a	+19.94 b	+429.3	— 1.1 div.	—0.6 μ
" 6	—129.9 div.	=	a	+16.52 b	+430.5	+ 0.1 div.	+0.1 μ
" 7	+146.6 div.	=	a	+ 8.25 b	+426.5	— 3.9 div.	—1.9 μ
" 7	—589.8 div.	=	a	+30.07 b	+430.2	— 0.2 div.	—0.1 μ
" 7	—594.8 div.	=	a	+30.14 b	+427.4	— 3.0 div.	—1.5 μ
" 8	— 15.2 div.	=	a	+12.92 b	+423.0	— 7.4 div.	—3.7 μ

Normal Equations.

$$-655.3 = 12\,a + 171.66\,b \qquad b = -33.92$$
$$-60293.1 = +171.66\,a + 3956.23\,b \qquad a = +436.4$$

Combining results, giving to the value of b the same weight in each series, we have

$$b = -34.28 \text{ div.} = -17.28\ \mu.$$

COMPARISON OF METERS T^{a_2}, T^{b_1}, *C. S.*, $R_1^{a_2}$, $R_1^{b_2}$, AND $R_2^{a_2}$ WITH UNIVERSAL COMPARATOR.

(Objective = 1 inch.)

(1 div. = 0.440 μ = .0001732 in.)

Date.	*Y* 61	$T^{a_2} - T^{b_1}$	$T^{a_2} - C.S.$	$T^{a_2} - R^{a_2}$	$T^{a_2} - R^{b_2}$	$T^{a_2} - R_2^{a_2}$
1883.	°	div.	div.	div.	div.	div.
Mar. 22	— 2.21	—13.8	+481.9	+125.8	....	+422.6
" 22	— 1.65	—13.8	+471 1	+126.5	....	+416.6
" 23	— 2.66	—13.1	+488.2	+124.4	....	+431.1
" 23	— 0.62	—14.0	+477.0	+154.1	....	+428.0
" 23	— 0.62	—13.7	+476.4	+151.3	....	+417.5
" 25	— 0.64	—16.4	+477.0	+149.6	....	+422.2
" 25	+ 0.14	—15.2	+477.8	+158.5	....	+424.0
" 25	+ 1.74	—15.5	+470.5	+175.1	....	+408.7
" 25	+ 2.20	—14.6	+468.5	+176.4	....	+413.4
" 25	+ 2 67	—15.8	+465.1	+179.8	....	+402.6
" 25	+ 2.45	—16.0	+462.1	+183.2	....	+407.7
" 26	+ 0.63	—14.0	+469.0	+150.9	....	+413.0
" 26	+ 0.85	—14.0	+469.2	+164.3	....	+409.0
" 26	+ 1.27	—14.4	+475.1	+174.0	....	+415.1
" 28	+ 6.40	—13.1	+463.0	+248.3	....	+404 7
" 29	+ 0.63	—14.0	+459.0	+149.9	....	+403.0
" 29	+ 0.42	—17.3	+467.4	+154.7	....	+410.0
" 29	+ 1.21	—15.1	+473.5	+171.2	....	+415.7
" 29	+ 1.92	—15.2	+473.4	+188.9	....	+414.2
" 30	— 0.48	—15.2	+472.4	+150.6	....	+415.5
" 30	— 0.29	—15.2	+475.2	+147.9	....	+419.0
" 30	+ 1.25	—13.3	+470.4	....	....	+416.1
Apr. 1	+ 0.10	—13.1	+469.6	+155.8	....	+408.7
" 1	+ 0.06	—15.7	+474.7	+162.0	....	+415.1
" 1	+ 0.04	—19.9	+462.6	+155.1	....	+407.9
" 1	+ 0.26	—13.7	+473.0	....	....	....
" 2	— 0.33	—13.4	+470.7	....	....	....
" 2	— 0.26	—16.8	+477.1	....	....	....
" 2	— 0.23	—15.8	+474.1	....	....	....
" 2	— 0.14	—14.8	+473.9	....	....	....
" 2	— 0.14	—13.7	+478.2	+150.3	....	+409.2
" 3	+ 3.98	—15.6	+473.8	+214.6	....	+409.5
" 3	+ 4.39	—13.4	+464.0	+218.4	....	+412.3
" 3	+ 4.63	—15.6	+468.1	+225.2	....	+406.8
" 3	+ 5.02	—14.4	+462.8	+228.9	....	+404.8
" 8	+13.24	—12.1	+424.6	+328.2	....	+379.8
" 8	+12.86	—16.8	+430.1	+332.4	....	+382.2
" 8	+12 23	—13.4	+441.1	+326.5	....	+387.4
" 8	+11.99	—13.1	+439.3	+324.0	....	+391.6
" 9	+10.54	—14.6	+447.7	+310.9	....	+395.6
" 9	+10.26	—14.8	+441.9	+299.8	....	+393.6
" 9	+10.23	—13.0	+444.5	+302.3	....	+393.7
" 10	+ 6.98	—12.6	+445.1	+249.5	....	+392.2
May 14	+14 68	—13.6	+435.9	+349.4	+356.4	+390.1
" 14	+14.68	—13.6	+436.3	+359.0	+346.4	+385.7

COMPARISON OF METERS. — Continued.

Date.	Y 61	$T^{a_2}—T^{b_1}$	$T^{a_2}—C.S.$	$T^{a_2}—R_1^{a_2}$	$T^{a_2}—R_1^{b_2}$	$T^{a_2}—R_2^{a_2}$
1883.	°	div.	div.	div.	div.	div.
May 15	+14.68	—20.4	+427.1	+356.4	+349.4	+386.1
" 15	+14.68	—12.9	+431.4	+369.2	+361.7	+382.0
" 16	+15.02	—14.3	+433.0	+369.6	+363.8	+389.4
" 17	+14.48	—16.4	+426.8	+356.5	+346.9	+383.3
" 17	+15.02	—18.2	+423.4	+369.1	+371.8	+377.9
" 18	+14.46	—15.9	+421.4	+364.3	+357.6	+377.0
" 19	+14.54	—15.0	+424.2	+353.8	+345.8	+381.7
" 20	+14.33	—18.6	+423.2	+352.7	+344.3	+383.2
" 20	+14.46	—13.3	+427.4	+352.4	+346.0	+384.5
" 20	+14.49	—17.0	+423.4	+363.4	+354.9	+384.9
" 21	+14.66	—16.5	+422.5	+357.4	+347.3	+381.0
" 21	+14.66	—16.3	+425.9	+357.9	+348.6	+380.5
" 22	+14.84	—16.6	+426.6	+363.4	+354.5	+384.7
" 23	+14.58	—17.3	+420.3	+354.2	+344.6	+382.8
" 23	+14.58	—16.4	+424.2	+355.3	+347.4	+385.6
" 24	+14.46	—18.4	+421.6	+343.5	+336.6	+374.5
" 24	+14.54	—16.8	+424.4	+348.6	+340.0	+376.8
" 24	+14.48	—16.0	+425.4	+353 3	+344.8	+381.1
" 25	+14.26	—14.6	+430 2	+362.2	+352.5	+389.3
" 25	+14.28	—15.9	+427.7	+349.6	+342.9	+382.0
" 27	+14.28	—18.2	+424.4	+350.6	+342.8	+382.4
" 27	+14.54	—18.6	+425.0	+354.7	+347.0	+383.5
" 28	+14.64	—17.7	+426.9	+356.2	+347.8	+381.0
" 29	+14.76	—18.0	+424.9	+356.4	+349.1	+380.6
" 30	+14.74	—18.3	+428.9	+366.9	+357.6	+388.5
" 30	+14.84	—15.1	+420.4	+354.8	+346.3	+378.7
" 31	+14.74	—16 8	+423.5	+354.7	+345.9	+380.2
" 31	+14.86	—16.6	+418.0	+352.1	+343.4	+376.6
June 1	+14.92	—12.1	+427.7	+370.2	+360.6	+385.6
" 1	+15.08	—16.9	+426.0	+362.0	+352.2	+384.4
" 3	+19.70	—16.5	+404.8	+415.7	+409.1	+362.2
" 3	+19.15	—16.6	+406.2	+417.7	+411.1	+369.2
" 3	+18.69	—15.0	+404.8	+419.3	+412.3	+364.0
" 4	+17.70	—17.9	+411.2	+392.3	+385.4	+375.5
" 4	+17.69	—15.6	+411.9	+397.7	+389.9	+375.8
" 4	+17.48	—14.9	+413.9	+394.9	+387.3	+374.9
" 4	+17.49	—16.5	+416.2	+392.2	+384.0	+376.1
" 5	+17.01	—13.5	+420.4	+393.5	+386.7	+332.0
" 5	+17.13	—16.5	+419 0	+400.2	+394.3	+382.1
" 6	+17.09	—16.1	+420.4	+400.2	+391.5	+377.7
" 7	+17.23	—17.5	+417.4	+400.5	+394.5	+378.5
" 7	+17.23	—17.1	+421.7	+400.4	+393.3	+379.1
" 25	+17.86	—17.0	+413.3	+397.5	+389.8	+368.3
" 26	+17.87	—16.5	+414.4	+402.2	+394.9	+370.1
" 26	+18.04	—15.1	+417.6	+406.6	+399.5	+374.0
" 27	+17.87	—13.9	+414.2	+402.9	+396.2	+371.7
" 27	+17.97	—14.6	+416.4	+408.4	+400.0	+371.6
" 27	+18.16	—16.6	+419.0	+414.1	+404.2	+377.4
" 28	+18.03	—18.0	+416.6	+405.5	+397.6	+373.2

COMPARISON OF YARDS *C.S.*, $R_1^{a_2}$, $R_1^{b_2}$, AND $R_2^{a_2}$ WITH UNIVERSAL COMPARATOR.

(Objective = 1 inch.)
(1 div. = 0.440 μ = .0001732 in.)

Date.	*Y* 61	$C.S. - R_1^{a_2}$	$C.S. - R_1^{b_2}$	$C.S. - R_2^{a_2}$
1883	°	div.	div.	div.
Mar. 22	− 1.65	−331.2	....	−62.7
“ 23	− 2.66	−346.8	....	−58.4
“ 23	− 0.62	−321.7	....	−63.6
“ 23	− 0.62	−316.6	....	−58.1
“ 25	− 0.64	−315.0	....	−61.3
“ 25	+ 1.74	−279.9	....	−54.7
“ 26	+ 0.63	−303.4	....	−62.8
“ 26	+ 0.85	−300.1	....	−62.0
“ 26	+ 1.27	−301.1	....	−60.0
“ 28	+ 6.40	−208.3	....	−53.7
“ 29	+ 0.63	−303.4	....	−62.6
“ 29	+ 0.42	−301.5	....	−63.2
“ 29	+ 1.21	−283.8	....	−53.8
“ 29	+ 1.92	−278.1	....	−57.7
“ 30	− 0.48	−315.5	....	−55.8
“ 30	− 0.29	−315.2	....	−56.6
“ 30	+ 1.25	−284.1	....	−54.7
Apr. 1	+ 0.10	−303.3	....	−52.7
“ 1	+ 0.06	−309.6	....	−62.0
“ 1	+ 0.04	−309.2	....	−59.9
“ 2	− 0.14	−310.4	....	−60.3
“ 3	+ 3.98	−252.3	....	−58.0
“ 3	+ 4.39	−237.4	....	−57.9
“ 3	+ 4.63	−240.3	....	−52.2
“ 3	+ 5.02	−233.7	....	−55.2
“ 8	+13.24	−105.9	....	−47.9
“ 8	+12.86	−115.0	....	−51.9
“ 8	+12.23	−118.5	....	−52.1
“ 8	+11.99	−122.1	....	−51.2
“ 9	+10.54	−153.1	....	−54.8
“ 9	+10.26	−144.7	....	−46.9
“ 9	+10.23	−150.6	....	−47.0
“ 10	+ 6.98	−202.4	....	−52.2
May 14	+14.68	− 89.3	....	−52.4
“ 15	+14.48	− 82.7	−83.1	−52.8
“ 15	+14.68	− 81.7	−81.1	−50.8
“ 16	+15.02	− 80.0	−82.0	−47.8
“ 17	+14.48	− 84.6	−84.9	−50.6
“ 17	+15.02	− 76.0	−77.9	−50.2
“ 18	+14.46	− 78.6	−79.7	−50.5

COMPARISON OF YARDS.—Continued.

Date.	Y 61	$C.S.-R_1^{a_2}$	$C.S.-R_1^{b_2}$	$C.S.-R_2^{a_2}$
1883.	°	div.	div.	div.
May 19	14.54	—84.9	—84.3	—50.3
" 20	14.33	—83.8	—85.8	—50.1
" 20	14.46	—85.3	—87.1	—49.7
" 20	14.49	—86.2	—88.7	—47.5
" 21	14.66	—82.3	—83.4	—48.6
" 21	14.66	—77.4	—79.5	—48.8
" 22	14.84	—85.4	—86.6	—49.2
" 23	14.58	—78.2	—80.8	—53.8
" 23	14.58	—87.5	—89.4	—51.7
" 24	14.46	—86.2	—87.7	—50.7
" 24	14.54	—91.0	—92.4	—45.1
" 24	14.48	—88.4	—88.5	—51.2
" 25	14.26	—95.8	—97.9	—55.6
" 25	14.28	—91.1	—91.9	—52.7
" 27	14.28	—94.0	—95.0	—55.0
" 27	14.54	—84.1	—85.5	—47.2
" 28	14.64	—91.4	—93.6	—50.8
" 29	14.76	—79.7	—82.4	—49.6
" 30	14.74	—86.3	—88.0	—51.7
" 30	14.84	—83.6	—86.6	—51.8
" 31	14.74	—84.9	—85.5	—52.0
" 31	14.86	—84.1	—84.8	—51.2
June 1	14.92	—80.1	—84.5	—50.9
" 1	15.08	—77.2	—78.7	—46.0
" 3	19.70	— 4.4	— 9.4	—48.5
" 3	19.15	— 3.3	— 6.5	—43.7
" 3	18.69	—20.8	—23.0	—47.6
" 4	17.70	—36.8	—39.1	—47.8
" 4	17.69	—41.1	—42.8	—48.6
" 4	17.48	—41.4	—43.2	—49.9
" 4	17.49	—39.5	—40.7	—44.8
" 5	17.01	—43.5	—46.0	—48.4
" 5	17.13	—44.8	—45.3	—47.6
" 6	17.07	—48.5	—40.6	—48.3
" 7	17.23	—46.2	—42.5	—49.1
" 7	17.23	—41.3	—45.5	—48.1
" 25	17.86	—32.0	—32.0	—49.1
" 26	17.87	—34.6	—35.6	—48.6
" 26	18.04	—35.0	—37.0	—48.5
" 27	17.87	—32.2	—34.0	—48.3
" 27	17.97	—29.6	—32.7	—48.7
" 27	18.16	—31.7	—30.7	—48.5
" 28	18.03	—32.1	—30.0	—49.2

EQUATIONS OF CONDITION BETWEEN METRES T^{a_2} AND $C.S.$

1883.	$T^{a}_{2} - C.S.$			$(0^\circ - \tau)$	$b = -3.05$ div. $T^{a_2} - C.S.$ At 0°	Δa	Δa
Mar. 22	+476.5 div.	=	a	— 1.93 b	+470.6 div.	—2.6 div.	—1.1 μ
" 23	+408.5 div.	=	a	— 1.30 b	+476.5 div.	+3.3 div.	+1.5 μ
" 25	+477.4 div.	=	a	— 0.25 b	+476.6 div.	+3.4 div.	+1.5 μ
" 25	+466.6 div.	=	a	+ 2.27 b	+473.5 div.	+0.3 div.	+0.1 μ
" 26	+471.1 div.	=	a	+ 0.92 b	+473.9 div.	+0.7 div.	+0.3 μ
" 28	+463.0 div.	=	a	+ 6.40 b	+472.5 div.	—0.7 div.	—0.3 μ
" 29	+468.4 div.	=	a	+ 1.05 b	+471.6 div.	—1.6 div.	—0.7 μ
" 30	+471.8 div.	=	a	— 0.38 b	+472.6 div.	—0.6 div.	—0.3 μ
" 30	+470.4 div.	=	a	+ 1.25 b	+474.2 div.	+1.0 div.	+0.4 μ
April 1	+468.9 div.	=	a	+ 0.07 b	+469.1 div.	—4.1 div.	—1.8 μ
" 2	+474.2 div.	=	a	— 0.14 b	+473.8 div.	+0.6 div.	+0.3 μ
" 3	+465.0 div.	=	a	+ 4.51 b	+478.8 div.	+5.6 div.	+2.5 μ
" 8	+433.8 div.	=	a	+12.58 b	+472.2 div.	—1.0 div.	—0.4 μ
" 9	+444.7 div.	=	a	+10.34 b	+476.2 div.	+3.0 div.	+1.3 μ
" 10	+445.1 div.	=	a	+ 6.98 b	+466.4 div.	—6.8 div.	—3.0 μ
					At 16°.67		
May 14	+426.1 div.	=	a	+14.68 b	+420.0 div.	+1.0 div.	+0.4 μ
" 15	+429.3 div.	=	a	+14.58 b	+422.9 div.	+3.9 div.	+1.7 μ
" 16	+423.0 div.	=	a	+15.02 b	+418.0 div.	—1.0 div.	—0.4 μ
" 17	+425.1 div.	=	a	+14.75 b	+419.2 div.	+0.2 div.	+0.1 μ
" 18	+421.4 div.	=	a	+14.46 b	+414.7 div.	—4.3 div.	—1.9 μ
" 19	+424.2 div.	=	a	+14.54 b	+417.7 div.	—1.3 div.	—0.6 μ
" 20	+424.5 div.	=	a	+14.43 b	+417.7 div.	—1.3 div.	—0.6 μ
" 21	+424.2 div.	=	a	+14.66 b	+418.1 div.	—0.9 div.	—0.4 μ
" 22	+426.6 div.	=	a	+14.84 b	+421.0 div.	+2.0 div.	+0.9 μ
" 23	+422.3 div.	=	a	+14.58 b	+415.9 div.	—3.1 div.	—1.4 μ
" 24	+423.8 div.	=	a	+14.49 b	+417.2 div.	—1.8 div.	—0.8 μ
" 25	+429.0 div.	=	a	+14.27 b	+421.7 div.	+2.7 div.	+1.2 μ
" 27	+424.7 div.	=	a	+14.41 b	+417.8 div.	—1.2 div.	—0.5 μ
" 28	+426.9 div.	=	a	+14.64 b	+420.7 div.	+1.7 div.	+0.7 μ
" 29	+424.9 div.	=	a	+14.76 b	+419.1 div.	+0.1 div.	+0.0 μ
May 30	+424.7 div.	=	a	+14.79 b	+419.0 div.	+0.0 div.	+0.0 μ
" 31	+420.8 div.	=	a	+14.80 b	+415.1 div.	—3.9 div.	—1.7 μ
June 1	+426.9 div.	=	a	+14.99 b	+421.8 div.	+2.8 div.	+1.2 μ
" 3	+405.8 div.	=	a	+19.18 b	+413.5 div.	—5.5 div.	—2.4 μ
" 4	+413.3 div.	=	a	+17.59 b	+416.1 div.	—2.9 div.	—1.3 μ

1883.		$T^{a_2} - C.\,S.$			$(0^\circ - \tau)$	$T^{a_2} - C.\,S.$ At 16°.67	Δa	Δa
June	5	+419.7 div.	=	a	$+17.07\,b$	+420.9 div.	+1.9 div.	$+0.8\,\mu$
"	6	+420.4 div.	=	a	$+17.07\,b$	+421.6 div.	+2.6 div.	$+1.1\,\mu$
"	7	+419.6 div.	=	a	$+17.23\,b$	+421.4 div.	+2.4 div.	$+1.1\,\mu$
"	25	+413.3 div.	=	a	$+17.86\,b$	+416.9 div.	—2.1 div.	$-0.9\,\mu$
"	26	+414.4 div.	=	a	$+17.87\,b$	+418.0 div.	—1.0 div.	$-0.4\,\mu$
"	26	+417.6 div.	=	a	$+18.04\,b$	+421.8 div.	+2.8 div.	$+1.2\,\mu$
"	27	+414.2 div.	=	a	$+17.87\,b$	+417.9 div.	—1.1 div.	$-0.5\,\mu$
"	27	+416.4 div.	=	a	$+17.97\,b$	+420.4 div.	+1.4 div.	$+0.6\,\mu$
"	27	+419.0 div.	=	a	$+18.16\,b$	+423.5 div.	+4.5 div.	$+2.0\,\mu$
"	28	+416.6 div.	=	a	$+18.03\,b$	+420.7 div.	+1.7 div.	$+0.7\,\mu$

Normal Equations.

$$\begin{aligned} +16696.6 &= 38\,a + 394.20\,b & b &= -3.33 \\ +167520.3 &= 394.20\,a + 5810.50\,b & a &= +473.9 \end{aligned}$$

Since it cannot be assumed that the relative coefficient between T and $C.S.$ for 0° is the same as for 16°.67, it will be advisable to derive the values of a and b from the observations made near these temperatures. From the observations between March 22 and April 10 inclusive, we have

$$\begin{aligned} +6969.4 &= 15\,a + 42.37\,b & b &= -3.09 \\ +18853.5 &= 42.37\,a + 389.4\,b & a &= +473.3 \end{aligned}$$

From the observations made between May 14 and June 7, we have

$$\begin{aligned} +9727.2 &= 23\,a + 351.83\,b & b &= -3.21 \\ +148666.8 &= 351.83\,a + 5421.10\,b & a &= +472.0 \end{aligned}$$

Whence between 0° and 16°.67,

$$b = -\frac{54.8}{16.67} = -3.29 \text{ div.} = -1.45\,\mu.$$

We have already found,

$$b = 16.22\,\mu - 17.45\,\mu = -1.23\,\mu.$$

Combining, we have,

$$b = \frac{-1.45\,\mu - 1.23\,\mu}{2} = -1.33\,\mu = -3.05 \text{ div.}$$

which is the value which has been used in obtaining the reduced values of $T^{a_2} - C.S.$

EQUATIONS OF CONDITION BETWEEN METERS T^{a_2} AND $R_1^{a_2}$.

1883.	$T^{a_2} - R_1^{a_2}$			$(\tau - 0^\circ)$	$b = +13.80$ div. $T^{a_2} - R_1^{a_2}$ At 0° C.	Δa	Δa
Mar. 22	+126.1 div.	=	*a*	— 1.93 *b*	+152.7 div.	—3.0 div.	—1.3 μ
" 23	+143.3 div.	=	*a*	— 1.30 *b*	+161.2 div.	+5.5 div.	+2.4 μ
" 25	+154.0 div.	=	*a*	— 0.25 *b*	+157.5 div.	+1.8 div.	+0.8 μ
" 25	+178.6 div.	=	*a*	+ 2.27 *b*	+147.3 div.	—8.4 div.	—3.7 μ
" 26	+163.1 div.	=	*a*	+ 0.92 *b*	+150.4 div.	—5.3 div.	—2.3 μ
" 28	+248.3 div.	=	*a*	+ 6.40 *b*	+160.0 div.	+4.3 div.	+1.9 μ
" 29	+166.2 div.	=	*a*	+ 1.05 *b*	+151.7 div.	—4.0 div.	—1.8 μ
" 30	+149.2 div.	=	*a*	— 0.38 *b*	+154.4 div.	—1.3 div.	—0.6 μ
" 30	+179.7 div.	=	*a*	+ 1.25 *b*	+162.4 div.	+6.7 div.	+2.9 μ
April 1	+157.6 div.	=	*a*	+ 0.07 *b*	+156.6 div.	+0.9 div.	+0.4 μ
" 2	+150.3 div.	=	*a*	— 0.14 *b*	+152 2 div.	—3.5 div.	—1.5 μ
" 3	+221.8 div.	=	*a*	+ 4.51 *b*	+159.6 div.	+3.9 div.	+1.7 μ
" 8	+327.7 div.	=	*a*	+12.58 *b*	+154.1 div.	—1.6 div.	—0.7 μ
" 9	+304.3 div.	=	*a*	+10.34 *b*	+161.6 div.	+5.9 div.	+2.6 μ
" 10	+249.5 div.	=	*a*	+ 6.98 *b*	+153.2 div.	—2.5 div.	—1.1 μ
					At 16°.67		
May 14	+354.2 div.	=	*a*	+14.68 *b*	+381.6 div.	—5 3 div.	—2.3 μ
" 15	+362.8 div.	=	*a*	+14.58 *b*	+391.6 div.	+4.7 div.	+2.1 μ
" 16	+369.6 div.	=	*a*	+15.02 *b*	+392.4 div.	+5.5 div.	+2.4 μ
" 17	+362.8 div.	=	*a*	+14.75 *b*	+389.3 div.	+2.4 div.	+1.1 μ
" 18	+364.3 div.	=	*a*	+14.46 *b*	+394.8 div.	+7.9 div.	+3.5 μ
" 19	+353.8 div.	=	*a*	+14.54 *b*	+383 2 div.	—3.7 div.	—1.6 μ
" 20	+356.2 div.	=	*a*	+14.43 *b*	+387.1 div.	+0.2 div.	+0.5 μ
" 21	+357.6 div.	=	*a*	+14.66 *b*	+385.4 div.	—1.5 div.	—0.7 μ
" 22	+363.4 div.	=	*a*	+14 84 *b*	+388.6 div.	+1.7 div.	+0.7 μ
" 23	+354.8 div.	=	*a*	+14.58 *b*	+383.6 div.	—3.3 div.	—1.5 μ
" 24	+348.5 div.	=	*a*	+14.49 *b*	+378.6 div.	—8.3 div.	—3.7 μ
" 25	+355.9 div.	=	*a*	+14.27 *b*	+389.0 div.	+2.1 div.	+0.9 μ
" 27	+352.7 div.	=	*a*	+14.41 *b*	+383.9 div.	—3.0 div.	—1.3 μ
" 28	+356.2 div.	=	*a*	+14.64 *b*	+384.2 div.	—2.7 div.	—1.2 μ
" 29	+356.4 div.	=	*a*	+14.76 *b*	+382.8 div.	—4.1 div.	—1.8 μ
May 30	+360.8 div.	=	*a*	+14.79 *b*	+386.7 div.	—0.2 div.	—0.1 μ
" 31	+353.4 div.	=	*a*	+14.80 *b*	+379.2 div.	—7.7 div.	—3.4 μ
June 1	+366.1 div.	=	*a*	+14.99 *b*	+389.3 div.	+2 4 div.	+1.1 μ
" 3	+417.6 div.	=	*a*	+19.18 *b*	+383.0 div.	—3.9 div.	—1.7 μ
" 4	+394.3 div.	=	*a*	+17.59 *b*	+381.6 div.	—5.3 div.	—2.3 μ

1883.	$T^{a_2} - R_1^{a_2}$			$(\tau - 0^\circ)$	$T^{a_2} - R_1^{a_2}$ At 16°.67	Δa	Δa
June 5	+396.8 div.	=	a	+17.07 b	+391.3 div.	+4.4 div.	+1.9 μ
" 6	+400.2 div.	=	a	+17.07 b	+394.7 div.	+7.8 div.	+3.4 μ
" 7	+400.4 div.	=	a	+17.23 b	+392.7 div.	+5.8 div.	+2.6 μ
" 25	+397.5 div.	=	a	+17.86 b	+381.1 div.	—5.8 div.	—2.6 μ
" 26	+404.2 div.	=	a	+17.87 b	+387.6 div.	+0.7 div.	+0.3 μ
" 26	+406.6 div.	=	a	+18.04 b	+387.6 div.	+0.7 div.	+0.3 μ
" 27	+402.9 div.	=	a	+17.87 b	+386.3 div.	—0.6 div.	—0.3 μ
" 27	+408.4 div.	=	a	+17.97 b	+390.4 div.	+3.5 div.	+1.5 μ
" 27	+414.1 div.	=	a	+18.16 b	+394.0 div.	+7.1 div.	+3.1 μ
" 28	+405.5 div.	=	a	+18.03 b	+386.7 div.	—0.2 div.	—0.1 μ

Normal Equations.

$$+11378.5 = +38\,a + 394.2\,b \qquad b = +13.80$$
$$+141584.9 = +394.2\,a + 5810.5\,b \qquad a = +156.2$$

EQUATIONS OF CONDITION BETWEEN METERS T^{a_2} AND $R_2^{a_2}$.

1883.	$T^{a_2} - R_2^{a_2}$			$(\tau - 0^\circ)$	$b = -2.29$ div. $T^{a_2} - R_2^{a_2}$ At 0° C.	Δa	Δa
Mar. 22	+419.6 div.	=	a	— 1.93 b	+415.2 div.	—0.4 div.	—0.2 μ
" 23	+425.6 div.	=	a	— 1.30 b	+422.6 div.	+7.0 div.	+3.1 μ
" 25	+423.1 div.	=	a	— 0.25 b	+422.4 div.	+6.8 div.	+3.0 μ
" 25	+408.1 div.	=	a	+ 2.27 b	+413.3 div.	—2.3 div.	—1.0 μ
" 26	+412.4 div.	=	a	+ 0.92 b	+414.5 div.	—1.1 div.	—0.5 μ
" 28	+404.7 div.	=	a	+ 6.40 b	+419.4 div.	+3.8 div.	+1.7 μ
" 29	+410.7 div.	=	a	+ 1.05 b	+413.1 div.	—2.5 div.	—1.1 μ
" 30	+417.2 div.	=	a	— 0.38 b	+416.3 div.	+0.7 div.	+0.3 μ
" 30	+416.1 div.	=	a	+ 1.25 b	+419.0 div.	+3.4 div.	+1.5 μ
Apr. 1	+410.6 div.	=	a	+ 0.07 b	+410.7 div.	—4.9 div.	—2.2 μ
" 2	+409.2 div.	=	a	— 0.14 b	+408.9 div.	—6.7 div.	—2.9 μ
" 3	+408.4 div.	=	a	+ 4.51 b	+418.8 div.	+3.2 div.	+1.4 μ
" 8	+385.2 div.	=	a	+12.58 b	+414.0 div.	—1.6 div.	—0.7 μ
" 9	+394.3 div.	=	a	+10.34 b	+418.0 div.	+2.4 div.	+1.1 μ
" 10	+392.2 div.	=	a	+ 6.98 b	+408.3 div.	—7.3 div.	—3.2 μ
					At 16°.67		
May 14	+387.9 div.	=	a	+14.68 b	+383.3 div.	+6.9 div.	+3.0 μ
" 15	+384.1 div.	=	a	+14.58 b	+379.3 div.	+2.9 div.	+1.3 μ
" 16	+389.4 div.	=	a	+15.02 b	+385.6 div.	+9.2 div.	+4.0 μ
" 17	+380.6 div.	=	a	+14.75 b	+376.2 div.	—0.2 div.	—0.1 μ
" 18	+377.0 div.	=	a	+14.46 b	+371.9 div.	—4.5 div.	—2.0 μ

1883.	$T^{a_2} - R_2^{a_2}$			$(\tau - 0^\circ)$	$T^{a_2} - R_2^{a_2}$ At 16°.67	Δa	Δa
May 19	+381.7 div.	=	a	+14.54 b	+376.8 div.	+0.4 div.	+0.2 μ
" 20	+384.2 div.	=	a	+14.43 b	+379.0 div.	+2.6 div.	+1.1 μ
" 21	+380.7 div.	=	a	+14.66 b	+376.1 div.	—0.3 div.	—0.1 μ
" 22	+384.7 div.	=	a	+14.84 b	+380.5 div.	+4.1 div.	+1.8 μ
" 23	+384.2 div.	=	a	+14.58 b	+379.4 div.	+3.0 div.	+1.3 μ
" 24	+377.5 div.	=	a	+14.49 b	+372.5 div.	—3.9 div.	—1.7 μ
" 25	+385.7 div.	=	a	+14.27 b	+380.2 div.	+3.8 div.	+1.7 μ
" 27	+382.9 div.	=	a	+14.41 b	+377.7 div.	+1.3 div.	+0.6 μ
" 28	+381.6 div.	=	a	+14.64 b	+376.9 div.	+0.5 div.	+0.2 μ
" 29	+380.6 div.	=	a	+14.76 b	+376.2 div.	—0.2 div.	—0.1 μ
" 30	+383.1 div.	=	a	+14.79 b	+378.8 div.	+2.4 div.	+1.1 μ
" 31	+378.4 div.	=	a	+14.80 b	+374.1 div.	—2.3 div.	—1.0 μ
June 1	+385.0 div.	=	a	+14.99 b	+381.1 div.	+4.7 div.	+2.1 μ
" 3	+365.1 div.	=	a	+19.18 b	+370.9 div.	—5.5 div.	—2.4 μ
" 4	+375.6 div.	=	a	+17.59 b	+377.7 div.	+1.3 div.	+0.6 μ
June 5	+382.0 div.	=	a	+17.07 b	+382.9 div.	+6.5 div.	+2.9 μ
" 6	+377.7 div.	=	a	+17.07 b	+378.6 div.	+2.2 div.	+1.0 μ
" 7	+378.0 div.	=	a	+17.23 b	+379.3 div.	+2.9 div.	+1.3 μ
" 25	+368.3 div.	=	a	+17.86 b	+371.1 div.	—5.3 div.	—2.3 μ
" 26	+370.1 div.	=	a	+17.87 b	+373.9 div.	—2.5 div.	—1.1 μ
" 26	+374.0 div.	=	a	+18.04 b	+370.9 div.	—5.5 div.	—2.4 μ
" 27	+371.7 div.	=	a	+17.87 b	+369.0 div.	—7.4 div.	—3.3 μ
" 27	+371.7 div.	=	a	+17.97 b	+368.7 div.	—7.7 div.	—3.4 μ
" 27	+377.4 div.	=	a	+18.16 b	+374.0 div.	—2.4 div.	—1.1 μ
" 28	+373.2 div.	=	a	+18.03 b	+370.1 div.	—6.3 div.	—2.8 μ

Normal Equations.

$$+14905.1 = +38\,a + 394.2\,b \qquad b = -2.29 = -1.01\,\mu$$

$$+150711.1 = +394.2\,a + 5810.5\,b \qquad a = +433.6 = +190.8\,\mu$$

EQUATIONS OF CONDITION BETWEEN YARDS *C. S.* AND $R_1^{a_2}$.

$b = +15.57$ div.

1883.	$C.S. - R_1^{a_2}$			$(\tau - 0^\circ)$	$C.S. - R_1^{a_2}$ At 0° C.	Δa	Δa
Mar. 22	—331.2 div.	=	a	— 1.93 b	—301.7 div.	—6.8 div.	—3.0 μ
" 23	—328.4 div.	=	a	— 1.30 b	—308.2 div.	—0.3 div.	—0.1 μ
" 25	—315.0 div.	=	a	— 0.64 b	—305.0 div.	—3.5 div.	—7.5 μ
" 25	—279.9 div.	=	a	+ 1.71 b	—307.0 div.	—1.5 div.	—0.7 μ
" 26	—301.5 div.	=	a	+ 0.92 b	—315.8 div.	+7.3 div.	+3.2 μ

1883.	$C.S. - R_1^{a_2}$			$(\tau - 0°)$	$C.S. - R_1^{a_2}$ At 0° C.	Δa	Δa
Mar. 28	—208.3 div.	=	a	+ 6.40 b	—307.9 div.	—0.6 div.	—0.3 μ
" 29	—291.7 div.	=	a	+ 1.05 b	—308.0 div.	—0.5 div.	—0.2 μ
" 30	—315.2 div.	=	a	— 0.38 b	—309.4 div.	+0.9 div.	+0.4 μ
" 30	—284.1 div.	=	a	+ 1.25 b	—303.6 div.	—4.9 div.	—2.2 μ
Apr. 1	—307.4 div.	=	a	+ 0.07 b	—308.5 div.	0.0 div.	0.0 μ
" 2	—310.4 div.	=	a	— 0.14 b	—308.2 div.	—0.3 div.	—0.1 μ
" 3	—241.1 div.	=	a	+ 4.51 b	—311.3 div.	+2.8 div.	+1.2 μ
" 8	—115.4 div.	=	a	+12.58 b	—311.3 div.	+2.8 div.	+1.2 μ
" 9	—149.5 div.	=	a	+10.34 b	—310.5 div.	+2.0 div.	+0.9 μ
" 10	—202.4 div.	=	a	+ 6.98 b	—311.1 div.	+2.6 div.	+1.1 μ
					At 16°.67		
May 14	— 89.3 div.	=	a	+14.68 b	— 58.3 div.	—5.6 div.	—2.5 μ
" 15	— 82.2 div.	=	a	+14.58 b	— 49.7 div.	+3.0 div.	+1.3 μ
" 16	— 80.0 div.	=	a	+15.02 b	— 54.3 div.	—1.6 div.	—0.7 μ
" 17	— 80.4 div.	=	a	+14.75 b	— 50.5 div.	+2.2 div.	+1.0 μ
" 18	— 78.6 div.	=	a	+14.46 b	— 44.2 div.	+8.5 div.	+3.7 μ
" 19	— 84.9 div.	=	a	+14.54 b	— 51.7 div.	+1.0 div.	+0.4 μ
" 20	— 85.1 div.	=	a	+14.43 b	— 50.2 div.	+2.5 div.	+1.1 μ
" 21	— 79.9 div.	=	a	+14.66 b	— 48.6 div.	+4.1 div.	+1.8 μ
" 22	— 85.4 div.	=	a	+14.84 b	— 56.9 div.	—4.2 div.	—1.8 μ
" 23	— 82.8 div.	=	a	+14.58 b	— 50.3 div.	+2.4 div.	+1.1 μ
" 24	— 88.3 div.	=	a	+14.49 b	— 54.4 div.	—1.7 div.	—0.7 μ
" 25	— 93.4 div.	=	a	+14.27 b	— 56.0 div.	—3.3 div.	—1.5 μ
" 27	— 89.0 div.	=	a	+14.41 b	— 53.8 div.	—1.1 div.	—0.5 μ
" 28	— 91.4 div.	=	a	+14.64 b	— 59.8 div.	—7.1 div.	—3.4 μ
" 29	— 79.7 div.	=	a	+14.76 b	— 50.0 div.	+2.7 div.	+1.2 μ
" 30	— 85.0 div.	=	a	+14.79 b	— 55.7 div.	—3.0 div.	—1.3 μ
" 31	— 84.5 div.	=	a	+14.80 b	— 55.4 div.	—2.7 div.	—1.2 μ
June 1	— 78.7 div.	=	a	+14.99 b	— 52.5 div.	+0.2 div.	+0.1 μ
" 3	— 9.5 div.	=	a	+19.18 b	— 48.6 div.	+4.1 div.	+1.8 μ
" 4	— 39.7 div.	=	a	+17.59 b	— 54.0 div.	—1.3 div.	—0.6 μ
June 5	— 44.1 div.	=	a	+17.07 b	— 50.4 div.	+2.3 div.	+1.0 μ
" 6	— 48.5 div.	=	a	+17.07 b	— 54.8 div.	—2.1 div.	—0.9 μ
" 7	— 43.7 div.	=	a	+17.23 b	— 52.4 div.	+0.3 div.	+0.1 μ
" 25	— 32.0 div.	=	a	+17.86 b	— 50.5 div.	+2.2 div.	+1.0 μ
" 26	— 34.6 div.	=	a	+17.87 b	— 53.3 div.	—0.6 div.	—0.3 μ
" 26	— 35.0 div.	=	a	+18.04 b	— 56.3 div.	—3.6 div.	—1.6 μ
" 27	— 32.2 div.	=	a	+17.87 b	— 50.9 div.	+1.8 div.	+0.8 μ
" 27	— 29.6 div.	=	a	+17.97 b	— 49.8 div.	+2.9 div.	+1.3 μ
" 27	— 31.7 div.	=	a	+18.16 b	— 54.9 div.	—2.2 div.	—1.0 μ
" 28	— 32.1 div.	=	a	+18.03 b	— 53.3 div.	—0.6 div.	—0.3 μ

Normal Equations.

$$-5685.7 = +38\,a + 394.2\,b \qquad b = +15.53 = +6.83\,\mu$$
$$-32302.0 = +394.2\,a + 5807.1\,b \qquad a = -310.7 = -136.7\,\mu$$

This value of b reduced to the equivalent for one meter becomes $7.48\,\mu$.

But from

$$T - C.\,S. \qquad b = -3.29 \text{ div.}$$
$$T - R_1 \qquad b = +13.80 \text{ div.}$$

Whence from

$$C.\,S. - R_1. \qquad b = +17.09 = +7.52\,\mu.$$

We have, therefore, for 1 meter,

$$b = \frac{+7.48\,\mu + 7.52\,\mu}{2} = +7.50\,\mu = +17.04 \text{ div.}$$

For 1 yard,

$$b = \frac{+6.83\,\mu + 6.87\,\mu}{2} = +6.85\,\mu = +15.57 \text{ div.}$$

EQUATIONS OF CONDITION BETWEEN YARDS $C.S.$ AND $R_2^{a_2}$.

1883.	$C.S. - R_2^{a_2}$		$(\tau - 0°)$	$b = +0.69$ div. $C.S. - R_2^{a_2}$ At 0° C.	Δa	Δa
Mar. 22	—62.7 div.	=	$a - 1.93\,b$	—61.3 div.	+3.0 div.	$+1.3\,\mu$
" 23	—60.0 div.	=	$a - 1.30\,b$	—59.1 div.	+0.8 div.	$+0.4\,\mu$
" 25	—61.3 div.	=	$a - 0.64\,b$	—60.9 div.	+2.6 div.	$+1.1\,\mu$
" 25	—54.7 div.	=	$a + 1.74\,b$	—55.9 div.	—2.4 div.	$-1.1\,\mu$
" 26	—61.6 div.	=	$a + 0.92\,b$	—62.2 div.	+3.9 div.	$+1.7\,\mu$
" 28	—53.7 div.	=	$a + 6.40\,b$	—58.1 div.	—0.2 div.	$-0.1\,\mu$
" 29	—59.3 div.	=	$a + 1.05\,b$	—54.6 div.	—3.7 div.	$-1.6\,\mu$
" 30	—56.2 div.	=	$a - 0.38\,b$	—55.9 div.	—2.4 div.	$-1.1\,\mu$
" 30	—54.7 div.	=	$a + 1.25\,b$	—55.6 div.	—2.7 div.	$-1.2\,\mu$
Apr. 1	—58.2 div.	=	$a + 0.07\,b$	—58.2 div.	—0.1 div.	$-0.0\,\mu$
" 2	—60.3 div.	=	$a - 0.14\,b$	—60.2 div.	+1.9 div.	$+0.8\,\mu$
" 3	—55.8 div.	=	$a + 4.51\,b$	—59.0 div.	+0.7 div.	$+0.3\,\mu$
" 8	—50.8 div.	=	$a + 12.58\,b$	—59.5 div.	+1.2 div.	$+0.5\,\mu$
" 9	—49.6 div.	=	$a + 10.34\,b$	—56.7 div.	—1.6 div.	$-0.7\,\mu$
" 10	—52.2 div.	=	$a + 6.98\,b$	—57.0 div.	—1.3 div.	$-0.6\,\mu$
				At 16°.67		
May 14	—52.4 div.	=	$a + 14.68\,b$	—51.0 div.	—1.9 div.	$-0.8\,\mu$
" 15	—51.8 div.	=	$a + 14.58\,b$	—50.4 div.	—1.3 div.	$-0.6\,\mu$
" 16	—47.8 div.	=	$a + 15.02\,b$	—46.7 div.	+2.4 div.	$+1.1\,\mu$
" 17	—50.4 div.	=	$a + 14.75\,b$	—49.1 div.	0.0 div.	$0.0\,\mu$
" 18	—50.5 div.	=	$a + 14.46\,b$	—49.0 div.	+0.1 div.	$0.0\,\mu$

1883.		$C.S. - R_2^{c_2}$			$(\tau - 0°)$	$C.S. - R_2^{c_2}$ At 16.°67	Δa	Δa
May	19	—50.3 div.	=	a	$+14.54\,b$	—48.8 div.	+0.3 div.	$+0.1\,\mu$
“	20	—49.1 div.	=	a	$+14.43\,b$	—47.5 div.	+1.6 div.	$+0.7\,\mu$
“	21	—48.7 div.	=	a	$+14.66\,b$	—47.3 div.	+1.8 div.	$+0.8\,\mu$
“	22	—49.2 div.	=	a	$+14.84\,b$	—47.9 div.	+1 2 div.	$+0.5\,\mu$
“	23	—52.8 div.	=	a	$+14.58\,b$	—51.3 div.	—2.2 div.	$-1.0\,\mu$
“	24	—49.0 div.	=	a	$+14.49\,b$	—47.5 div.	+1.6 div.	$+0.7\,\mu$
“	25	—54.1 div.	=	a	$+14.27\,b$	—52.4 div.	—3.3 div.	$-1.5\,\mu$
“	27	—51.1 div.	=	a	$+14.41\,b$	—49.5 div.	—0.4 div.	$-0.2\,\mu$
“	28	—50.8 div.	=	a	$+14.64\,b$	—49.4 div.	—0.3 div.	$-0.1\,\mu$
“	29	—49.6 div.	=	a	$+14.76\,b$	—48.3 div.	+0.8 div.	$+0.4\,\mu$
“	30	—51.7 div.	=	a	$+14.79\,b$	—50.5 div.	—1.4 div.	$-0.6\,\mu$
“	31	—51.6 div.	=	a	$+14.80\,b$	—50.4 div.	—1.3 div.	$-0.6\,\mu$
June	1	—48.4 div.	=	a	$+14.99\,b$	—47.3 div.	+1.8 div.	$+0.8\,\mu$
“	3	—46.6 div.	=	a	$+19.18\,b$	—48.3 div.	+0.8 div.	$+0.4\,\mu$
“	4	—47.8 div.	=	a	$+17.59\,b$	—48.4 div.	+0.7 div.	$+0.3\,\mu$
“	5	—48.0 div.	=	a	$+17.07\,b$	—48.3 div.	+0.8 div.	$+0.4\,\mu$
“	6	—48.3 div.	=	a	$+17.07\,b$	—48.6 div.	+0.5 div.	$+0.2\,\mu$
“	7	—48.6 div.	=	a	$+17.23\,b$	—49.0 div.	+0.1 div.	$+0.0\,\mu$
“	25	—49.1 div.	=	a	$+17.86\,b$	—50.0 div.	—0.9 div.	$-0.4\,\mu$
“	26	—48.6 div.	=	a	$+17.87\,b$	—49.4 div.	—0.3 div.	$-0.1\,\mu$
“	26	—48.5 div.	=	a	$+18.04\,b$	—49.5 div.	—0.4 div.	$-0.2\,\mu$
“	27	—48.3 div.	=	a	$+17.87\,b$	—49.1 div.	0.0 div.	$0.0\,\mu$
“	27	—48.7 div.	=	a	$+17.97\,b$	—49.6 div.	—0.5 div.	$-0.2\,\mu$
“	27	—48.5 div.	=	a	$+18.16\,b$	—49.5 div.	—0.4 div.	$-0.2\,\mu$
“	28	—49.2 div.	=	a	$+18.03\,b$	—50.1 div.	—1.0 div.	$-0.4\,\mu$

Normal Equations.

$$-1999.6 = +38\,a + 394.2\,b \qquad b = +0.63 = +0.28\,\mu$$

$$-19663.9 = +394.2\,a + 5807.1\,b \qquad a = -59.2 = -26.0\,\mu$$

From

$$T - R_2 \qquad b = -1.01\,\mu$$

$$T - C.\,S. \qquad b = -1.34\,\mu$$

Whence from

$$C.\,S. - R_2 \qquad b = +0.33\,\mu$$

We have, therefore,

$$\text{For 1 yard,} \qquad b = \frac{+0.28\,\mu + 0.30\,\mu}{2} = +0.29\,\mu = +0.69 \text{ div.}$$

$$\text{For 1 meter,} \qquad b = \frac{+0.33\,\mu + 0.31\,\mu}{2} = +0.32\,\mu = +0.73 \text{ div.}$$

COMPARISON OF METERS T^{a_2}, T^{b_1}, $R_1^{a_2}$, $R_1^{b_2}$, AND YARDS $R_1^{a_2}$, $R_1^{b_2}$.

Date.	Y 61	$T^{a_2} - T^{b_1}$ Meter.	Δa	Δa	$R_1^{a_2} - R_1^{b_2}$ Meter.	Δa	Δa	$R_1^{a_2} - R_1^{b_2}$ Yard.	Δa	Δa
1883.	°	div.	div.	μ	div.	div.	μ	div.	div.	μ
March 22	— 1.93	—13.8	+1.8	+0.8	....	....	....	....	....	....
" 23	— 1.30	—13.6	+2.0	+0.9	....	....	....	....	....	....
" 25	— 0.25	—15.8	—0 2	—0.1	....	....	....	....	....	....
" 25	+ 2.27	—15.5	+0.1	+0.0	....	....	....	....	....	....
" 26	+ 0.92	—14.1	+1.5	+0.7	....	....	....	....	....	....
" 28	+ 6.40	—13.1	+2.5	+1.1	....	....	....	....	....	....
" 29	+ 1.05	—15.4	+0.2	+0.1	....	....	....	....	....	....
" 30	— 0.38	—15.2	+0.4	+0 2	....	....	....	....	....	....
" 30	+ 1.25	—13.3	+2.3	+1.0	....	....	....	....	....	....
April 1	+ 0.07	—15.6	0.0	+0.0	....	....	....	....	....	....
" 2	— 0.14	—14 9	+0.7	+0.3	....	....	....	....	....	....
" 3	+ 4.51	—14.8	+0.8	+0.4	....	....	....	....	....	....
" 8	+12.58	—13 8	+1.8	+0.8	....	....	....	....	....	....
" 9	+10.34	—14.1	+1.5	+0.7	....	....	....	....	....	....
" 10	+ 6.98	—12 6	+3.0	+1.3	....	....	....	....	....	....
May 14	+14.68	—13.6	+2.0	+0.9	—9.8	—1 8	—0.8	....	....	....
" 15	+14.58	—16.6	—1.0	—0.4	—7.2	+0.8	+0.3	+0 1	+1.4	+0.6
" 16	+15.02	—14.3	+1 3	+0 6	—5.8	+2.2	+1.0	—2.0	—0 7	—0 3
" 17	+14.75	—17.3	—1.7	—0.7	—8 4	—0.4	—0.2	—1.1	+0.2	+0.1
" 18	+14.46	—15.9	—0.3	—0.1	—6.7	+1.3	+0.6	—1.1	+0.2	+0.1
" 19	+14.54	—15 0	+0.6	+0.3	—8.0	0.0	+0.0	+0.6	+1.9	+0.8
" 20	+14.43	—16 3	—0.7	—0 3	—7.8	+0.2	+0.1	—2.1	—0.8	—0.4
" 21	+14.66	—16.4	—0.8	—0.4	—9.7	—1.7	—0.7	—1.6	—0.3	—0.1
" 22	+14.84	—16.6	—1.0	—0.4	—8.9	—0 9	—0.4	—1.2	+0.1	+0.0
" 23	+14.58	—16.8	—1.2	—0.5	—8.7	—0.7	—0.3	—2.2	—0.9	—0.4
" 24	+14.49	—17.1	—1.5	—0.7	—8.0	0.0	+0.0	—1.0	+0.3	+0.1
" 25	+14.27	—15.2	+0.4	+0.3	—8.2	—0.2	—0.1	—1.4	—0.1	+0.0
" 27	+14.41	—18.4	—2.8	—1.2	—7.7	+0.3	+0.1	—1.2	+0.1	+0.1
" 28	+14.64	—17.7	—2.1	—0.9	—8.4	—0.4	—0 2	—2.2	—0.9	—0 4
" 29	+14.76	—18.0	—2.4	—1.1	—7.3	+0.7	+0.3	—2 7	—1.4	—0 6
" 30	+14.79	—16.7	—1.1	—0.5	—8.9	—0.9	—0.4	—2.3	—1.0	—0.4
" 31	+14.80	—16.7	—1.1	—0.5	—8.7	—0.7	—0.3	—0.6	+0.7	+0.3
June 1	+14.99	—16.7	—1.1	—0.5	—9.7	—1.7	—0.7	—2.9	—1.6	—0.7
" 3	+19.18	—16.0	—0.4	—0.2	—6.7	+1.3	+0.6	—3.5	—2 2	—1.0
" 4	+17.59	—16.2	—0.6	—0.3	—7.6	+0.4	+0.2	—1.7	—0.4	—0.2
" 5	+17.07	—15.0	+0.6	+0 3	—6.3	+1.7	—0.7	—1.5	—0.2	—0.1
" 6	+17.07	—16.1	—0.5	—0.2	—8.7	—0.7	—0.3	0.0	+1.3	+0 6
" 7	+17.23	—17.3	—1.7	—0.7	—6.5	+1.5	+0.7	—0.2	+1.1	+0.5
" 25	+17.86	—17.0	—1 4	—0.6	—7.7	+0.3	+0.1	0 0	+1.3	+0.6
" 26	+17.89	—16 5	—0.9	—0.4	—9.5	—1.5	—0.7	—1.0	+0.3	+0.1
" 26	+18.04	—15.1	+0.5	+0.2	—7.1	+0.9	+0.4	—2.0	—0.7	—0.3
" 27	+17.87	—13.9	+1.7	+0.7	—6.7	+1 3	+0.6	—2.0	—0.7	—0.3
" 27	+17.97	—14 6	+1.0	+0.4	—8.4	—0.4	—0.2	—3 1	—1.8	—0.8
" 27	+18.16	—16.6	—1.0	—0.4	—9.9	—1.9	—0.8	+1.0	+2.3	+1 0
" 28	+18 03	—18.0	—2.4	—1.1	—7.9	+0.1	+0.0	+2.1	+3.4	+1.5
Mar. 22 to Mar. 26	....	—14.56	+1.05	+0.46	....	....	....	....	....	....
Mar. 28 to Apr 1	....	—14.52	+1.09	+0.48	....	....	....	....	....	....
Apr. 2 to Apr. 10	....	—14.04	+1 57	+0.51	....	....	....	....	....	....
May 14 to May 18	....	—15 44	+0.17	+0.07	—7.58	+0.45	+0.20	—1.02	+0.24	+0.11
May 19 to May 23	....	—16.22	—0.61	—0.27	—8.62	—0.59	—0.26	—1.30	—0.04	—0.01
May 24 to May 29	....	—17.25	—1.64	—0.72	—7 92	+0.11	+0.05	—1.70	—0.44	—0.19
May 30 to June 4	....	—16 46	—0.85	—0 37	—8.32	—0.29	—0.13	—2.20	—0.94	—0.41
June 5 to June 26	....	—16.38	—0.77	—0.35	—7.74	+0.29	+0.13	—0.54	+0.72	+0 32
June 26 to June 28	....	—15.64	—0.03	—0.01	—8.00	+0.03	+0.01	—0.80	+0.46	+0.20
MEANS........	....	—15.61 = —6.87 μ			—8.03 = —3.53 μ			—1.26 = —0.55 μ		

COMPARISON OF METERS *C. S.*, R_1, AND R_2.

At 0° and at 16.67°.

Date.	τ	$C.S. - R_1^{a2}$	$C.S. - R_1^{a2}$ At 0° C.	Δa	Δa	$C.S. - R_2^{a2}$	$C.S. - R_2^{a2}$ At 0° C.	Δa	Δa
1883.	°	div.	div.	div.	μ	div.	div.	div.	μ
Mar. 22	— 1.93	—350.4	—317.9	—0.3	—0.1	—56.9	—55.4	+ 2.2	+1.0
" 23	— 1.30	—337.2	—315.3	+2.3	+1.0	—54.9	—53.9	+ 3.7	+1.6
" 25	— 0.25	—323.4	—319.2	—1.6	—0.7	—54.3	—54.2	+ 3.4	+1.5
" 25	+ 2.27	—288.0	—326.2	—8.6	—3.8	—58.5	—60.2	— 2.6	—1.1
" 26	+ 0.92	—308.0	—323.5	—5.9	—2.6	—58.7	—59.4	— 1.8	—0.8
" 28	+ 6.40	—204.7	—312.5	+5.1	+2.2	—48.3	—53.1	+ 4.5	+2.0
" 29	+ 1.05	—302.2	—319.9	—2.3	—1.0	—57.7	—58.5	— 0.9	—0.4
" 30	— 0 38	—324.6	—318.2	—0.6	—0.3	—56.7	—56.3	+ 1.3	+0 6
" 30	+ 1.25	—290.7	—311.8	+5.8	+3.8	—54.3	—55.2	+ 2.4	+1.0
Apr. 1	+ 0.07	—311.3	—312.5	+5.1	+2.2	—58.3	—58.4	— 0.8	—0.4
" 2	— 0.14	—323.9	—321 6	—4.0	—1.8	—65.0	—64.9	— 7.3	—3.2
" 3	+ 4.51	—243.2	—319.2	—1.6	—0.7	—56.6	—60.0	— 2.4	—1.1
" 8	+12.58	—106.1	—318.1	—0.3	—0.1	—48.6	—58.2	— 0.6	—0.3
" 9	+10.34	—140.4	—314.6	+3.0	+1.3	—50.4	—58.2	— 0.6	—0.3
" 10	+ 6.98	—195.6	—313.2	+4.4	+1.9	—52.9	—58.1	— 0.5	—0.2
			At 16°.67				At 16°.67		
May 14	+14.68	— 71.9	— 38.4	—6.3	—2.8	—38.2	—36.7	+ 5.9	+2.6
" 15	+14.58	— 66.5	— 31.3	+0.8	+0.4	—45.2	—43.6	— 1.0	—0.4
" 16	+15.02	— 53.4	— 25.6	+6.5	+2.9	—33.6	—32.4	+10.2	+4.5
" 17	+14.75	— 62.3	— 29.9	+2.2	+1.0	—44.5	—43.0	— 0.4	—0.2
" 18	+14.46	— 57.1	— 19.9	+12.2	+5.4	—44.4	—42.8	— 0.2	—0.1
" 19	+14.54	— 70.4	— 34.5	—2.4	—1.1	—42.5	—40.9	+ 1.7	+0.7
" 20	+14.43	— 68.3	— 30.6	+1.5	+0.7	—40.3	—38.7	+ 3.9	+1.7
" 21	+14 66	— 66.6	— 32.7	—0.6	—0.3	—43.5	—42.0	+ 0.6	+0.3
" 22	+14.84	— 63.2	— 32.4	—0.3	—0.1	—41.9	—40.5	+ 2.1	+0.9
" 23	+14.58	— 67.5	— 32.3	—0.2	—0.1	—38.1	—36.5	+ 6.1	+2.7
" 24	+14.49	— 75.3	— 38.6	—6.5	—2.9	—46.3	—44.7	— 2.1	—0.9
" 25	+14.27	— 73.1	— 32.7	—0.6	—0.3	—43.3	—41.5	+ 1.1	+0.5
" 27	+14.41	— 72.0	— 33.9	—1.8	—0.8	—41.8	—40.1	+ 2.5	+1.1
" 28	+14.64	— 70.7	— 36.5	—4.4	—1.9	—45.3	—43.8	— 1.2	—0.5
" 29	+14.76	— 68.5	— 36.3	—4.2	—1.8	—44.3	—42.9	— 0.3	—0.1
" 30	+14.79	— 63.9	— 32.3	—0.2	—0.1	—41.6	—40.2	+ 2.4	+1.1
" 31	+14.80	— 67.4	— 35.9	—3.8	—1.7	—42.4	—41.0	+ 1.6	+0.7
June 1	+14.99	— 60.8	— 32.5	—0.4	—0.2	—41.9	—40.7	+ 1.9	+0.7
" 3	+19.18	+ 11.8	— 30.5	+1.6	+0.7	—40.7	—42.6	+ 0.0	+0.0
" 4	+17.59	— 19.0	— 34.5	—2.4	—1.1	—37.7	—38.4	+ 4.2	+1.8
" 5	+17.07	— 22.9	— 29.6	+2.5	+1.1	—37.7	—38.0	+ 4.6	+2.0
" 6	+17.07	— 20.2	— 26.9	+5.2	+2.3	—42.7	—43.0	— 0.4	—0.2
" 7	+17.23	— 19.2	— 28.7	+3.4	+1.5	—41.6	—42.1	+ 0.5	+0.2
" 25	+17.86	— 15.8	— 35.8	—3.7	—1.6	—45.0	—45.8	— 3.2	—1.4
" 26	+17.89	— 10.2	— 30.4	+1.7	+0.7	—44.3	—44.1	— 1.5	—0.7
" 26	+18.04	— 11.0	— 34.2	—2.1	—0.9	—43.6	—50.9	— 8.3	—3.7
" 27	+17.87	— 11.3	— 31.6	+0.5	+0.2	—42.5	—48.9	— 6.3	—2.8
" 27	+17.97	— 8.0	— 30.0	+2.1	+0.9	—44.7	—51.7	— 9.1	—4.0
" 27	+18.16	— 4.9	— 29.5	+2.6	+1.1	—41.6	—49.5	— 6.9	—3.1
" 28	+18.03	— 11.1	— 34.0	—1.9	—0.8	—43.4	—50.6	— 8.0	—0.4

COMPARISON OF METERS R_1 AND R_2, AND OF YARDS R_1 AND R_2.

At 0° and at 16.67°.

Date.	τ	Meters.		Δa	Δa	Yards.		Δa	Δa
		$R_1^{a_2} - R_2^{a_2}$	$R_1^{a_2} - R_2^{a_2}$ At 0° C.			$R_1^{a_2} - R_2^{a_2}$	$R_1^{a_2} - R_2^{a_2}$ At 0° C.		
1883.	°			div.	μ			div.	μ
Mar. 22	— 1.93	+293.5	+262.5	+ 2.5	+1.1	+269.1	+240.4	—9.8	—4.3
" 23	— 1.30	+282.3	+261.4	+ 1.4	+0.6	+268.4	+248.9	—1 3	—0.6
" 25	— 0.25	+269.1	+264.9	+ 4.9	+2.2	+253.7	+244.1	—6.1	—2.7
" 25	+ 2 27	+229.5	+266.0	+ 6.0	+2.6	+225.2	+251.1	+0.9	+0.4
" 26	+ 0.92	+249.3	+264.1	+ 4.1	+1.8	+239.9	+253.6	+3.4	+1.5
" 28	+ 6.40	+156.4	+259.4	— 0.4	—0.2	+184 6	+249.8	—0.4	—0.2
" 29	+ 1.05	+244.5	+261 4	+ 1.4	+0.6	+237.8	+253.4	+3.2	+1.5
" 30	— 0.38	+267.9	+261.9	+ 1.9	+0.8	+259.1	+253.5	+3.3	+1.5
" 30	+ 1.25	+236.4	+256.6	— 3.4	—1.5	+229.4	+248.0	—2.2	—1.0
Apr. 1	+ 0.07	+253.0	+254.1	— 5.9	—2.6	+249.2	+250.3	+0.1	+0 0
" 2	— 0.14	+258.9	+256.7	— 3.3	—1.5	+250.1	+247.9	—2 3	—1 0
" 3	+ 4.51	+186.6	+259.2	— 0.8	—0.4	+185 3	+252.3	+2.1	+0.9
" 8	+12.58	+ 57.5	+259.9	— 0.1	+0.0	+ 64.6	+251.8	+1.6	+0.7
" 9	+10.34	+ 90.0	+256.4	— 3.6	—1.6	+ 99.9	+253.8	+3 6	+1.6
" 10	+ 6.98	+142.7	+255.1	— 4.9	—2.2	+150.2	+254.1	+3.9	+1.7
							At 16° 67		
May 14	+14.68	[+ 33.7]	[+ 1.7]	+ . .	[+0.7]	+ 36.9	+ 7.3	+3.4	+1.5
" 15	+14 58	+ 21.3	— 12.3	— 1.3	—0.6	+ 30.4	— 0.7	—4.6	—2.0
" 16	+15.02	+ 19.8	— 6.8	+ 4.2	+1.8	+ 32.2	+ 7.6	+3 7	+1.7
" 17	+14.75	+ 17.8	— 13.1	— 2 1	—0.9	+ 30.0	+ 1.4	—2.5	—1.1
" 18	+14.46	+ 12.7	— 22.9	[—11.9]	[—5.2]	+ 28.1	[— 4.8]	[—8.7]	[—3.8]
" 19	+14.54	+ 27.9	— 6 4	+ 4 6	+2.0	+ 34.6	+ 2.9	—1.0	—0.4
" 20	+14.43	+ 28.0	— 8.1	+ 2.9	+1.3	+ 36.0	+ 2.7	—1.2	—0.5
" 21	+14 66	+ 23.1	— 9.3	+ 1.7	+0.7	+ 31.2	+ 1.3	—2.6	—1.1
" 22	+14.84	+ 21 3	— 8.1	+ 2 9	+1.3	+ 36.2	+ 9.0	+5.1	+2.2
" 23	+14.58	+ 29.4	— 4.2	+ 6.8	+3.0	+ 30.0	— 1.0	—4.9	—2.2
" 24	+14.49	+ 29.0	— 6.1	+ 4.9	+2.2	+ 39.3	+ 6.9	+3.0	+1.3
" 25	+14.27	+ 29.8	— 8.8	+ 2.2	+0 9	+ 39.3	+ 3 6	—0.3	—0.1
" 27	+14.41	+ 30.2	— 6 2	+ 4.8	+2 1	+ 37.9	+ 4 3	+0.4	+0.2
" 28	+14.64	+ 25.4	— 7.3	+ 3.7	+1.6	+ 40.6	+ 10.4	+6.5	+2.9
" 29	+14.76	+ 24.2	— 6.6	+ 4.4	+1.9	+ 30.1	+ 1.7	—2.2	—1.0
" 30	+14.79	+ 22.3	— 7.9	+ 3.1	+1.4	+ 33.3	+ 5.2	+1.3	+0.6
" 31	+14.80	+ 25.0	— 5.1	+ 5.9	+2.6	+ 32.9	+ 5.0	+1.1	+0.5
June 1	+14.99	+ 18.9	— 8.2	+ 2.8	+1.2	+ 30.3	+ 5.2	+1.3	+0.6
" 3	+19.18	— 52.5	— 12.1	— 1.1	—0.5	+ 37.1	+ 0.3	—3.6	—1.6
" 4	+17.59	— 18.7	— 3.9	+ 7.1	+3.1	— 8.1	+ 5.6	+1.7	+0.7
" 5	+17.07	— 14 8	— 8.4	+ 2.6	+1.1	— 3.9	+ 2.1	—1.8	—0.8
" 6	+17.07	— 22.5	— 16.1	— 5.1	—2 2	+ 0.2	+ 6.2	+2.3	+1.0
" 7	+17.23	— 22.4	— 13.4	— 2.4	—1.1	— 4.9	+ 3.4	—0.5	—0.2
" 25	+17.86	— 29.2	— 10 0	+ 1.0	+0.4	— 17.1	+ 0.5	—3.4	—1.5
" 26	+17.89	— 34.1	— 13.7	— 2.7	—1.2	— 14.0	+ 3.9	0.0	+0.0
" 26	+18.04	— 32.6	— 16.7	— 5.7	—2.3	— 13 5	+ 6.8	+2.9	+1.3
" 27	+17 87	— 31 2	— 17.3	— 6.3	—2.8	— 16 1	+ 1.8	—2.1	—0.9
" 27	+17.97	— 36.7	— 21.7	—10.7	—4.7	— 19.1	+ 0.2	—3.7	—1.6
" 27	+18.16	— 36.7	— 20.0	— 9.0	—4.0	— 16.8	+ 5.4	+1 5	+0.7
" 28	+18.03	— 32.3	— 16.6	— 5.6	—5.5	— 17.1	+ 3.2	—0.7	—0.3

COLLECTION OF RESULTS IN GROUPS OF FIVE DATES EACH.

Meters.

At 0° C.

	T^{a_2}—$C.S.$	T^{a_2}—$R_1^{a_2}$	T^{a_2}—$R_2^{a_2}$	$C.S.$—$R_1^{a_2}$	$C.S.$—$R_2^{a_2}$	$R_1^{a_2}$—$R_2^{a_2}$
	div.	div.	div.	div.	div.	div.
	+474.2	+153.8	+417.6	—320.4	—56.6	+263.8
	+472.0	+157.0	+415.7	—315.0	—56.3	+258.7
	+473.5	+156.1	+413.6	—317.4	—59.9	+257.5
Means	+473.2	+155.6	+415.6	—317.6	—57.6	+260.0

At 16°.67 C.

	+419.0	+389.9	+379.8	—29.1	—39.7	—10.6
	+418.1	+385.6	+378.4	—32.5	—39.7	— 7.2
	+419.3	+383.7	+376.7	—35.6	—42.6	— 7.0
	+417.1	+384.0	+376.5	—33.1	—40.6	— 7.5
	+419.8	+389.5	+377.2	—30.3	—42.6	—12.3
	+420.9	+389.0	+370.5	—31.9	—50.4	—18.5
Means	+419.0	+386.9	+376.4	—32.1	—42.6	—10.5

Whence the following relative coefficients are derived:—

For $T - C.\,S.$
$$b = \frac{+473.2 - 419.0}{16.67} = +3.25 = +1.43\,\mu$$

$T - R_1$
$$b = \frac{+155.6 - 386.9}{16.67} = -13.87 = -6.10\,\mu$$

$T - R_2$
$$b = \frac{+415.6 - 376.4}{16.67} = +2.35 = +1.03\,\mu$$

$C.\,S. - R_1$
$$b = \frac{-317.6 + 32.1}{16.67} = -17.12 = -7.53\,\mu$$

$C.\,S. - R_2$
$$b = \frac{-57.6 + 42.6}{16.67} = -0.90 = -0.40\,\mu$$

$R_1 - R_2$
$$b = \frac{+260.0 + 10.5}{16.67} = +16.23 = +7.14\,\mu$$

Converting b for $C.\,S. - R_1$, $C.\,S. - R_2$, and $R_1 - R_2$ into the equivalent values for 1 yard, we have

For $C.\,S. - R_1$ $\quad b = -6.91\,\mu$

$C.\,S. - R_2$ $\quad b = -0.36\,\mu$

$R_1 - R_2$ $\quad b = +6.54\,\mu$

Yards.

At 0° C.

	$C.S.-R_1^{a_2}$	$C.S.-R_2^{a_2}$	$R_1^{a_2}-R_2^{a_2}$
	div.	div.	div.
	—307.5	—60.0	+247.5
	—307.5	—56.5	+251.0
	—310.5	—58.5	+252.0
Means	—308.5	—58.3	+250.2
At 16°.67 C.			
	—51.4	—49.2	+2.2
	—51.5	—48.6	+2.9
	—54.8	—49.4	+5.4
	—53.2	—48.9	+4.3
	—52.3	—49.1	+3.2
	—53.0	—49.6	+3.4
Means	—52.7	—49.1	+3.6

Hence: —

For $C.S.-R_1$ $$b=\frac{-308.5+52.7}{16.67}=-15.35=-6.75\mu$$

$C.S.-R_2$ $$b=\frac{-58.3+49.1}{16.67}=-0.55=-0.24\mu$$

R_1-R_2 $$b=\frac{+250.2-3.6}{16.67}=+14.80=+6.51\mu$$

Converting these values into the equivalent values for 1 meter, we have

For $C.S.-R_1$ $b=-7.38\mu$
$C.S.-R_2$ $b=-0.27\mu$
R_1-R_2 $b=+7.12\mu$

Combining these results, we have

	For 1 Meter.	For 1 Yard.
For $T-C.S.$	$b=+1.43\mu$	$b=+1.31\mu$
$T-R_1$	$b=-6.10\mu$	$b=-5.58\mu$
$T-R_2$	$b=+1.03\mu$	$b=+0.94\mu$
$C.S.-R_1$	$b=-7.46\mu$	$b=-6.83\mu$
$C.S.-R_2$	$b=-0.33\mu$	$b=-0.30\mu$
R_1-R_2	$b=+7.13\mu$	$b=+6.52\mu$

Thus far there is no conclusive evidence that any of these coefficients vary in value with the temperature. For the present, therefore, it will be assumed that they are constant between the limits 0° and 16°.67. In order to compare the relative coefficients for *T*, *C. S.*, and R_2 derived from the absolute coefficients of these bars, it will be better to re-determine absolute coefficients from such observations as are symmetrically disposed about these limits. The following table contains the observations which fall within the limits 0° ± 8° and 16°.67 ± 8°.

The following corrections have been applied to the values under the first series for each bar, in order to reduce them to the system of the second series, viz.:—

For *T* corr. = —13.8 div.
C. S. corr. = —14.1 div.
R_2 corr. = —20.4 div.

DETERMINATION OF THE ABSOLUTE COEFFICIENTS OF METERS *T*, *C. S.*, AND R_2, FROM THE NORMAL VALUES FOR 0° AND 16°.67.

For the temperatures $(\tau - 0°)$ the reductions to 0° have been made with the values of b derived from the normal equations.

The value assumed for $(16°.67 - \tau)$ is written at the head of the column.

Bar T. $b = +32.18$ div.

Date.	$(\tau - 0°)$	$S - T^{b_1}$	Means by Groups.	Date.	$(16°.67 - \tau)$	$S - T^{b_1}$	Means by Groups.
1883.	°	div.	div.	1883.	°	div.	div.
Feb. 7	+1.76	+60.7		Feb. 11	+3.20	—476.9	
" 7	+3.83	+57.8		" 19	—7.86	—480.4	
" 7	+7.60	+59.6		" 25	+9.09	—473.2	
" 8	—4.30	+65.1		" 25	+8.36	—469.6	
" 8	+1.46	+53.8	+59.4	" 26	—5.70	—475.6	—475.1
" 9	—4.54	+61.3		Mar. 3	—2.66	—476.8	
" 12	+1.78	+61.4		Apr. 15	—2.74	—472.6	
" 12	—2.96	+59.5		" 17	+4.42	—474.9	
" 12	—0.79	+59.0		" 18	+7.53	—472.9	
" 13	+1.69	+62.2	+60.7	" 19	+8.03	—474.6	—474.4
" 13	+0.12	+60.8		" 20	—1.29	—475.3	
" 13	+3.26	+65.2		" 24	—3.80	—471.6	
" 14	—6.50	+56.5		" 25	—3.37	—478.4	
" 15	+5.82	+57.5		" 26	—4.59	—474.7	
" 16	+0.78	+61.0	+60.2	" 27	+7.65	—475.8	—475.2

Bar T. — Continued.

Date.	$(\tau - 0°)$	$S - T^{b_1}$	Means by Groups.	Date.	$(16°.67 - \tau)$	$S - T^{b_1}$	Means by Groups.
1883.	°	div.	div.	1883.	°	div.	div.
Feb 20	—1.92	+57.0		Apr. 27	+0.30	—475.3	
“ 25	+2.96	+63.0		“ 28	—1.87	—473.9	
“ 27	—6.71	+63.1		“ 29	+1.32	—473.1	
“ 27	+2.91	+61.5		“ 29	+0.66	—475.1	
“ 28	—3.47	+63.1	+61.5	“ 30	+0.79	—474.4	—474.4
“ 28	—0.22	+63.0		“ 30	—1.09	—475.0	
“ 28	—0.71	+63.5		May 1	—1.01	—472.5	
Mar. 1	+3.64	+62.1		“ 1	+0.11	—476.4	
“ 4	—0.35	+59.2		“ 2	+7.95	—475.1	
“ 5	—4.38	+66.7	+62.9	“ 4	—1.40	—467.4	—473.3
“ 5	—1.18	+65.6		“ 4	—1.49	—469.9	
Apr. 22	+4.57	+59.9		“ 4	—3.45	—470.8	
“ 23	+5.97	+60.9		“ 6	+0.20	—472.2	
“ 24	+6.02	+59.5		“ 7	+8.75	—476.8	
“ 25	+5.67	+60.1	+61.2	“ 8	+3.80	—473.6	—472.7
Bar C. S. $b = +34.63$ div.							
1883.	°	div.		1883	°	div.	
Feb. 12	—6.14	+483.2		Feb. 26	—5.29	—85.7	
“ 12	—1.15	+488.8		Mar. 3	—2.60	—95.8	
“ 13	+4.69	+490.0		Apr. 18	+7.82	—89.4	
“ 13	—7.76	+488.3		“ 19	—6.21	—92.0	
“ 14	—4.87	+490.2	+488.1	“ 20	—1.12	—93.6	—91.3
“ 15	+6.14	+481.3		“ 21	—0.12	—96.8	
“ 16	—1.44	[+473.7]		“ 22	—7.81	—97.8	
“ 20	—2.96	[+476.7]		“ 25	—3.72	—89.3	
“ 25	+1.75	+490.4		“ 25	—4.15	—91.4	
“ 27	+0.67	[+475.4]	+485.8	“ 28	—2.04	—93.1	—93.7
“ 28	—2.58	+488.7		May 1	—0.02	—88.1	
“ 28	—1.07	+487.4		“ 2	—1.42	—98.8	
“ 28	—0.11	+487.1		“ 2	—2.32	—96.7	
“ 28	—0.80	+486.5		“ 2	—2.48	—91.0	
“ 28	—2.33	+485.0	+486.9	“ 3	—1.80	—99.0	—94.7
“ 28	—3.76	+484.0		“ 3	—1.15	—97.5	
“ 28	+3.13	+487.2		“ 3	—1.54	—88.8	
Mar. 1	+5 65	+482.5		“ 4	—1.68	—96.7	
“ 4	—8.06	+484.4		“ 6	+0.17	—86.1	
“ 4	—4.40	+493.6	+486.3	“ 6	—0.79	—96.3	
				“ 6	—0.04	—91.3	—92.8
“ 4	—0.89	+484.8					
“ 19	+6.70	+482.7					
Apr. 22	+4.07	+482 2					
“ 23	+5.79	+485.8					
“ 23	+5.88	+487.3	+484.6				
“ 24	+5.77	+485.1					
“ 25	+2.23	+485.4					
“ 26	+1.54	+479.0					
“ 27	+4.97	+485.9					
May 2	+7.55	+477.0	+482.6				

Bar R_2

Date.	$(\tau - 0^\circ)$	$S - T^{b_1}$	Means by Groups.	Date.	$(16^\circ.67 - \tau)$	$S - T^{b_1}$	Means by Groups.
1883.	°	div.	div.	1883.		div.	
Feb. 12	+0.58	+431.9		Feb. 11	+3.66	—135.4	
" 12	—1.31	+429.4		" 25	+8.19	—131.5	
" 13	+1.52	+421.4		" 26	—3.79	[—152.1]	
" 14	+1.81	+437.0		" 26	—4.36	—135.0	
" 15	+4.89	+433.4	+430.6	Mar. 31	—2.57	—126.0	—132.0
" 16	—2.28	+419.2		May 4	—1.38	—124.9	
" 16	+3.65	+427.9		" 4	—3.11	—136.5	
" 27	+3.17	+429.6		" 4	—3.27	—135.4	
" 27	+2.05	+444.2		" 6	+0.15	—135.6	
" 28	—4.35	+427.7	+429.7	" 8	+3.75	—143.3	—135.1
Mar. 2	+4.27	+427.9					
" 3	+3.25	+432.4					
" 7	+8.25	+426.6	+429.0				

Collecting results, we have

For $S - T$ For 0° C. For 16°.67.

$a = +61.0$ div. $= +30.7\,\mu$ $a = -474.2$ div. $= -239.1\,\mu$

Whence $b = +32.10$ div. $= +16.18\,\mu$

For $S - C.S.$

$a = +488.7$ div. $= +246.3\,\mu$ $a = -93.1$ div. $= -46.9\,\mu$

Whence $b = +34.90$ div. $= +17.59\,\mu$

For $S - R_2$

$a = +429.8$ div. $= +216.6\,\mu$ $a = -133.6$ div. $= -67.3\,\mu$

whence $b = +33.80$ div. $= +17.04\,\mu$

We have therefore, from these absolute coefficients, the following relative values.

From	$S - T$	$b = +16.18\,\mu$
	$S - C.S.$	$b = +17.59\,\mu$
	$S - R_2$	$b = +17.04\,\mu$
Whence for	$T - C.S.$	$b = +1.41\,\mu$
	$T - R_2$	$b = +0.86\,\mu$
	$C.S. - R_2$	$b = -0.55\,\mu$

Combining these values with the relative values found from the observations with the universal comparator, we have finally the following values for the absolute coefficients:—

Standards.	Coeff. for 1 Meter.	Coeff. for 1 Yard.
T	$+16.18\,\mu$	$+14.80\,\mu$
$C. S.$	$\frac{17.59+17.61}{2} = 17.60\,\mu$	$16.09\,\mu$
R_1	$\frac{10.08+10.14}{2} = 10.11\,\mu$	$9.24\,\mu$
R_2	$\frac{17.21+17.27+17.04}{3} = 17.17\,\mu$	$15.70\,\mu$

We are now prepared to place side by side the relations obtained from the comparison of T, $C. S.$, and R_2 with the standard S in melting ice and the values found by direct comparisons upon the universal comparator. The constant reduction from T^{b_1} to $T^{a_2} = 6.9\,\mu$ is first applied to the observed values $S - T$, $S - C. S.$, and $S - R_2$.

Meters.

	From Comparisons upon the Universal Comparator.				From Comparisons with Bars in Melting Ice.			
	At 0° C.	Wt.	At 16°.67 C.	Wt.	At 0° C.	Wt.	At 16°.67	Wt.
$T^{a_2} - C.S.$	$+208.2\,\mu$	4	$+184.4\,\mu$	4	$+208.7\,\mu$	1	$+185.3\,\mu$	1
$T^{a_2} - R_1^{a_2}$	$+\ 68.4\,\mu$	4	$+170.2\,\mu$	4	....	.	....	.
$T^{a_2} - R_2^{a_2}$	$+182.9\,\mu$	4	$+165.6\,\mu$	4	$+179.0\,\mu$	1	$+164.9\,\mu$	1
$C.S. - R_1^{a_2}$	$-139.7\,\mu$	4	$-\ 14.1\,\mu$	4	....	.	....	.
$C.S. - R_2^{a_2}$	$-\ 25.3\,\mu$	4	$-\ 18.7\,\mu$	4	$-\ 22.8\,\mu$	1	$-\ 13.5\,\mu$	1
$R_1^{a_2} - R_2^{a_2}$	$+114.4\,\mu$	4	$-\ 4.6\,\mu$	4	....	.	....	.

Adopted Relations for the Meter.

		At 0° C.		At 16°.67 C.
$T^{a_2} - C. S.$	=	$+208.3\,\mu$	=	$+184.6\,\mu$
$T^{a_2} - R_1^{a_2}$		$+\ 68.4\,\mu$		$+170.2\,\mu$
$T^{a_2} - R_2^{a_2}$		$+182.1\,\mu$		$+165.5\,\mu$
$C. S. - R_1^{a_2}$		$-139.7\,\mu$		$-\ 14.1\,\mu$
$C. S. - R_2^{a_2}$		$-\ 24.8\,\mu$		$-\ 17.7\,\mu$
$R_1^{a_2} - R_2^{a_2}$		$+114.4\,\mu$		$-\ 4.6\,\mu$

Adopted Relations for the Yard.

	At 0° C.	At 16°.67 C.
$C. S. - R_1^{a_2}$	$= -135.7\,\mu$	$= -23.2\,\mu$
$C. S. - R_2^{a_2}$	$= -\ 25.6\,\mu$	$= -21.6\,\mu$
$R_1^{a_2} - R_2^{a_2}$	$= +110.1\,\mu$	$= +\ 1.6\,\mu$

We have now the data for the direct comparison of the independent prototypes T and $C. S.$ of the Metre des Archives, both at 0° and at 16°.67. Representing the Metre des Archives by A, we have:

According to Tresca.	According to Pernet.
$T^{a}_{2} - 118.9\,\mu = A$ at 13°.70 C.	$C. S. + 310.0\,\mu = A$ at 0° C.

With the determined coefficients 16.18 μ and 17.60 μ for T and $C. S.$ respectively, we have

At 0° C. $\quad T^{a_2} + 102.8\,\mu = A$

But at 0° $\quad C. S. + 310.0\,\mu = A$

Hence $\quad T^{a_2} - CS = +207.2\,\mu$

From observation $\quad T^{a_2} - C. S. = +208.3\,\mu$

$\text{Diff.} = \quad 1.1\,\mu$

At 16°.67, $\quad T^{a_2} - 167.0\,\mu = A$

$C. S. + 16.6\,\mu = A$

Hence $\quad T^{a_2} - C. S. = +183.6\,\mu$

From observation $\quad T^{a_2} - C. S. = +184.6\,\mu$

$\text{Diff.} = \quad 1.0\,\mu$

We have therefore an agreement which is quite as close as one ought to expect.

For the yard we have, from observations at Washington,

$$\text{At } 16°.67,\ R_2 + 1.22\,\mu = Y = \text{Imperial Yard.}$$

From the Report of Mr. Chaney,

$C. S. + 20.68\,\mu = Y$

Hence $\quad C. S. - R_2^{a_2} = -19.5\,\mu$

From observation $\quad C. S. - R_2^{a_2} = -21.6\,\mu$

Diff. $\quad = \quad 2.1\,\mu$

Here again the agreement is extraordinarily close. It may be assumed, therefore, that the meters T and $C. S.$ represent the Metre des Archives within the limits of the ordinary errors of observation. The agreement, also, of the yard $C. S.$ by direct comparison with the Imperial Yard with the relation established through "Bronze 11," indicates that both of these standards represent the Imperial Yard when the determined corrections are applied. In the determination of the length of the meters and yards $R_1^{a_1}$ and $R_2^{a_2}$ it will be assumed that T and $C. S.$, with the determined corrections, represent the original standards with equal weight.

We have, therefore,

At 0° C.

$$T^{a_2} - A = -102.8\,\mu$$

But

$$T^{a_2} - R_1^{a_2} = +\ 68.4\,\mu$$

$$T^{a_2} - R_2^{a_2} = +182.1\,\mu$$

Whence

$$R_1^{a_2} - A = -171.2\,\mu$$

$$R_2^{a_2} - A = -284.9\,\mu$$

Also

$$C.\ S. - A = -310.0\,\mu$$

But

$$C.\ S. - R_1^{a_2} = -139.7\,\mu$$

$$C.\ S. - R_2^{a_2} = -\ 24.8\,\mu$$

Whence

$$R_1^{a_2} - A = -170.3\,\mu$$

$$R_2^{a_2} - A = -285.2\,\mu$$

At 16°.67 C.

$$T^{a_2} - A = +167.0\,\mu$$

But

$$T^{a_2} - R_1^{a_2} = +170.2\,\mu$$

$$T^{a_2} - R_2^{a_2} = +165.5\,\mu$$

Whence

$$R_1^{a_2} - A = \quad -3.2\,\mu$$

$$R_2^{a_2} - A = \quad +1.5\,\mu$$

Also

$$C.\ S. - A = -16.6\,\mu$$

But

$$C.\ S. - R_1^{a_2} = -14.1\,\mu$$

$$C.\ S. - R_2^{a_2} = -17.7\,\mu$$

Whence

$$R_{1}{}^{a}{}_{2} - A = -2.5\,\mu$$

$$R_2^{a_2} - A = +1.1\,\mu$$

We have therefore, finally, by combination,

At 0° C.

$$\mathbf{R_1^{a_2} + 170.7\,\mu = A}$$

$$\mathbf{R_2^{a_2} + 285.1\,\mu = A}$$

At 16°.67 C.

$$\mathbf{R_1^{a_2} + 2.8\,\mu = A}$$

$$\mathbf{R_2^{a_2} - 1.3\,\mu = A}$$

It will be observed that the relation for $R_2^{a_2}$ for 16°.67 is nearly identical with that determined in 1880 and 1881.

For the yard we have the following final results.

According to

$\frac{\text{Rogers} + \text{Smith}}{2}$ $\quad R_2^{a_2} - Y \quad = -\ 1.2\,\mu$

Chaney $\quad C.\ S. - Y \quad = -20.7\,\mu$

From observations $\quad C.\ S. - R_2^{a_2} = -21.6$

Whence $\quad R_2^{a_2} - Y \quad = +\ 0.9$

And finally,

At 16°.67 C.

$$R_2^{a_2} + 0.2\,\mu \qquad = Y$$

or,

$$R_2^{a_2} + .000008 \text{ in.} = Y$$

For $R_1^{a_2}$ we have, since

$$R_1^{a_2} - R_2^{a_2} \qquad = +1.6\,\mu$$

$$R_1^{a_2} - 1.4\,\mu \qquad = Y$$

or,

$$R_1^{a_2} - .000056 \text{ in.} = Y$$

COMPARISON OF METERS $R_1^{a_2}$, $G_1^{a_2}$, AND $G_2^{a_2}$, WITH UNIVERSAL COMPARATOR.

(Objective = 1 inch. 1 div. = .440 μ.)

	Equations of Condition.					At 0° C. $b = +4.5$ div.	
Date. 1883.	$R_1^{a_2} - G_1^{a_2}$		$R_1^{a_2} - G_2^{a_2}$		$(\tau - 0)^\circ$	$R_1^{a_2} - G_1^{a_2}$	$R_1^{a_2} - G_2^{a_2}$
Jan. 9	—15.7 div.	....	— 4.6 div.	= *a*	+8.506	(—53.9) div.	(—42.8) div.
" 9	—14.6 div.	....	—15.1 div.	= *a*	+6.046	(—41.9) div.	(—42.4) div.
" 10	—48.9 div.	....	—46.9 div.	= *a*	—4.046	—30.7 div.	—28.7 div.
" 11	—35.2 div.	....	—29.0 div.	= *a*	—1.386	—29.0 div.	—22.8 div.
" 12	—66.0 div.	....	—62.9 div.	= *a*	—7.666	—31.5 div.	—28.4 div.
" 12	—51.6 div.	....	—51.2 div.	= *a*	—7.706	(—16.0) div.	(—15.6) div.
" 12	—53.0 div.	....	—58.4 div.	= *a*	—7.566	(—19.0) div.	—24.4 div.
" 12	—49.9 div.	....	—48.2 div.	= *a*	—4.536	—29.5 div.	—27.8 div.
" 14	+20.4 div.	....	+17.6 div.	= *a*	+11.786	—32.6 div.	—35.4 div.
" 19	+32.7 div.	....	+33.2 div.	= *a*	+13.826	—29.5 div.	—29.0 div.
" 21	+18.1 div.	....	+21.4 div.	= *a*	+11.856	—35.2 div.	—31.9 div.
						At 16°.67 C.	
Jan. 14	+33.4 div.	....	+35.5 div.	= *a*	+15.776	+37.4 div.	+39.5 div.
" 15	+31.4 div.	....	+26.5 div.	= *a*	+14.446	+41.4 div.	+36.5 div.
" 17	+48.7 div.	....	+58.9 div.	= *a*	+21.116	(+28.7) div.	+38.9 div.
" 17	+57.6 div.	....	+65.7 div.	= *a*	+20.926	+38.5 div.	+46.6 div.
" 17	+56.5 div.	....	+66.4 div.	= *a*	+20.586	+38.9 div.	+48.8 div.
" 18	+38.3 div.	....	+43.9 div.	= *a*	+14.86	+46.4 div.	+52.0 div.
" 18	+51.0 div.	....	+52.3 div.	= *a*	+18.92	+40.9 div.	+42.2 div.
July 6	+51.0 div.	....	+54.0 div.	= *a*	+18.48	+42.9 div.	+45.9 div.
" 8	+66.1 div.	....	+72.9 div.	= *a*	+21.72	+43.4 div.	+50.2 div.
" 8	+62.6 div.	....	+70.5 div.	= *a*	+20.78	+44.1 div.	+52.0 div.
" 9	+56.5 div.	....	+66.1 div.	= *a*	+20.25	+40.4 div.	+50.0 div.
" 9	+56.5 div.	....	+63.9 div.	= *a*	+19.95	+41.7 div.	+49.1 div.

Date. 1883.	$R_1^{a_2} - G_1^{a_2}$		$R_1^{a_2} - G_2^{a_2}$		$(\tau - 0)^\circ$	At 16°.67 C. $R_1^{a_2} - G_1^{a_2}$	At 16°.67 C. $R_1^{a_2} - G_2^{a_2}$
July 10	+53.6 div.	....	+55.9 div.	=	a +19.53	+40.7 div.	+43.0 div.
" 10	+55.1 div.	....	+69.4 div.	=	a +19.49	+42.4 div.	+56.7 div.
" 11	+58.3 div.	....	+63.1 div.	=	a +19.11	+47.3 div.	+52.1 div.
" 11	+54.6 div.	....	+56.1 div.	=	a +19.13	+43.5 div.	+45.0 div.
" 12	+54.0 div.	....	+61.2 div.	=	a +19.20	+42.6 div.	+49.8 div.
" 12	+59.5 div.	....	+62.8 div.	=	a +19.07	+48.7 div.	+52.0 div.
" 13	+53.7 div.	....	+63.5 div.	=	a +19.08	+42.9 div.	+52.7 div.
" 13	+53.4 div.	....	+61.8 div.	=	a +19.08	+42.6 div.	+51.0 div.

Normal Equations.

For $R_1^{a_2} - G_2^{a_2}$

$$+788.1 = 31\,a + 400.6\,b$$
$$+22821.6 = 400.6\,a + 8141.3\,b$$
$$b = -4.27$$
$$a = -29.8$$

For $R_1^{a_2} - G_2^{a_2}$

$$+926.3 = 31\,a + 400.6\,b$$
$$+25256.0 = 400.6\,a + 8141.3\,b$$
$$b = -4.48$$
$$a = -28.0$$

COMPARISON OF YARDS $R_1^{a_2}$, $G_1^{a_2}$, AND $G_2^{a_2}$, WITH UNIVERSAL COMPARATOR.

Equations of Condition.

Date. 1883.	$R_1^{a_2} - G_1^{a_2}$	$R_1^{a_2} - G_2^{a_2}$		$(\tau - 0)^\circ$	At 0° C. $b = +4.1$ $R_1^{a_2} - G_1^{a_2}$	At 0° C. $b = +4.1$ $R_1^{a_2} - G_2^{a_2}$
Jan. 9	−13.2 div.	−10.0	=	$a + 8.50\,b$	(−48.0) div.	(−44.8) div.
" 9	−19.9 div.	− 8.7	=	$a + 6.04\,b$	(−44.7) div.	−33.5 div.
" 10	−42.8 div.	−31.8	=	$a - 4.04\,b$	−26.2 div.	(−15.2) div.
" 11	−26.2 div.	−30.8	=	$a - 1.38\,b$	−20.5 div.	−25.1 div.
" 12	−64.9 div.	−66.7	=	$a - 7.66\,b$	−33.8 div.	−35.3 div.
" 12	−59.7 div.	−61.5	=	$a - 7.70\,b$	−28.1 div.	−29.9 div.
" 12	−61.4 div.	−65.3	=	$a - 7.56\,b$	−30.4 div.	−34.3 div.
" 12	−43.9 div.	−37.3	=	$a - 4.53\,b$	−25.3 div.	−18.7 div.
" 14	+13.2 div.	+ 8.0	=	$a + 11.78\,b$	−35.1 div.	−40.3 div.
" 19	+27.2 div.	+29.3	=	$a + 13.82\,b$	−29.5 div.	−27.4 div.
" 21	+20.0 div.	+23.6	=	$a + 11.85\,b$	−28.6 div.	−25.0 div.
					At 16°.67 C.	
" 14	+29.6 div.	+28.8	=	$a + 15.77\,b$	+33.3 div.	+32.5 div.
" 15	+34.1 div.	+32.5	=	$a + 14.44\,b$	+43.2 div.	+41.6 div.
" 17	+46.4 div.	+59.6	=	$a + 21.11\,b$	(+28.2) div.	+41.4 div.
" 17	+56.2 div.	+57.4	=	$a + 20.92\,b$	+38.8 div.	+40.0 div.
" 17	+53.0 div.	+55.3	=	$a + 20.58\,b$	+37.0 div.	+39.3 div.
" 18	+38.0 div.	+32.9	=	$a + 14.86\,b$	+45.4 div.	+40.3 div.
" 18	+47.2 div.	+52.4	=	$a + 13.92\,b$	+38.0 div.	+43.2 div.
July 6	+48.0 div.	+49.0	=	$a + 13.48\,b$	+40.6 div.	+41.6 div.
" 8	+65.4 div.	+64.1	=	$a + 21.72\,b$	+44.7 div.	+43.4 div.
" 8	+56.0 div.	+60.9	=	$a + 20.78\,b$	+39.1 div.	+44.0 div.

Date.					At 16°.67 C.	
1883.	$R_1^{a_2} - G_1^{a_2}$	$R_1^{a_2} - G_2^{a_2}$		$(\tau - 0)^\circ$	$R_1^{a_2} - G_1^{a_2}$	$R_1^{a_2} - G_2^{a_2}$
July 9	+56.3 div.	+56.2	=	a +20.25 b	+41.6 div.	+41.5 div.
" 9	+55.7 div.	+53.4	=	a +19.95 b	+42.3 div.	+39.9 div.
" 10	+61.0 div.	+60.8	=	a +19.53 b	+49.3 div.	+49.1 div.
" 10	+51.3 div.	+51.3	=	a +19.41 b	+39.7 div.	+39.7 div.
" 11	+54.7 div.	+56.1	=	a +19.11 b	+44.7 div.	+46.1 div.
" 11	+58.7 div.	+52.0	=	a +19.13 b	+48.6 div.	+41.9 div.
" 12	+50.2 div.	+51.8	=	a +19.20 b	+39.8 div.	+41.4 div.
" 12	+53.5 div.	+54.3	=	a +19.07 b	+43.7 div.	+44.5 div.
" 13	+51.5 div.	+52.2	=	a +19.08 b	+41.6 div.	+42.3 div.
" 13	+54.1 div.	+50.8	=	a +19.08 b	+44.2 div.	+40.9 div.

Normal Equations.

For $R_1^{a_2} - G_1^{a_2}$	For $R_1^{a_2} - G_2^{a_2}$
$+739.3 = 31\,a + 400.6\,b$	$+780.6 = 31\,a + 400.6\,b$
$+22148.0 = 400.6\,a + 8141.3\,b$	$+22476.3 = 400.6\,a + 8141.3\,b$
$b = +4.25$	$b = +4.18$
$a = -31.1$	$a = -28.8$

The two values of b for the yard when reduced to the equivalent for one meter become 4.66 div. and 4.57 div. respectively. The mean value of b, therefore, derived from these equations, is 4.49 div. for one meter, or 4.10 div. for one yard. Substituting these values in the equations, we find a few values of a which differ from the mean value more than four times the probable error of a single value. In the formation of the mean values for 0° and for 16°.67 these quantities have been rejected.

For the meter, we have

	At 0°	At 16°.67	
$R_1^{a^2} - G_1^{a^2} =$	-31.1 div.	$+42.3$ div.	$b = +4.40$ div.
$R_1^{a^2} - G_2^{a^2} =$	-28.6 div.	$+47.7$ div.	$b = +4.58$ div.
		Mean . .	$+4.49$ div.

For the yard, we have

$R_1^{a^2} - G_1^{a^2} =$	-28.6 div.	$+41.9$ div.	$b = +4.23$ div.
$R_1^{a^2} - G_2^{a^2} =$	-29.9 div.	$+41.7$ div.	$b = +4.30$ div.
		Mean . .	$+4.26$ div.

We have, therefore, finally,

$$\text{For 1 meter,}\quad b = \frac{4.49\text{ div.} + 4.65\text{ div.}}{2} = +4.57\text{ div.} = 2.01\,\mu.$$

$$\text{For 1 yard,}\quad b = \frac{4.11\text{ div.} + 4.26\text{ div.}}{2} = 4.18\text{ div.} = 1.84\,\mu.$$

Since the absolute coefficient for R_1 is 10.11 μ, and 9.24 μ for the meter and yard, the absolute coefficient for the glass bars becomes 8.10 μ and 7.40 μ respectively for the meter and the yard.

Since for 16°.67,

For the Meter,		For the Yard,
$R_1^{a_2} + 2.8\,\mu = A$	and	$R_1^{a_2} - 1.4\,\mu = Y$
$R_1^{a_2} - 18.6\,\mu = G_1^{a_2}$		$R_1^{a_2} - 18.4\,\mu = G_1^{a_2}$
$R_1^{a_2} - 21.0\,\mu = G_2^{a_2}$		$R_1^{a_2} - 18.3\,\mu = G_2^{a_3}$

we have, finally,

$$G_1^{a_2} + 21.4\,\mu = A \qquad G_1^{a_2} + 17.0\,\mu = Y$$
$$G_2^{a_2} + 23.8\,\mu = A \qquad G_2^{a_2} + 16.9\,\mu = Y$$

The values which were actually used in the subsequent transfers, derived from a few of the earlier observations, were 21 μ for the meter and 15 μ for the yard.

It will be seen from the following observations that the second transfer was not quite successful, although the magnitude of the residuals is very much reduced. This part of my labor will not be considered as completed until a third transfer has been made, and until advantage can be taken of a lower temperature during the coming winter in order to obtain a more accurate value of the coefficient of expansion of the glass bar.

In the following tables, the values of $R_1^{a_2} - G_2^{b_2}$ and of $R_1^{a_2} - G_2^{d_2}$ have been reduced to $R_1^{a_2} - G_2^{b\frac{1\,2\,3}{3}}$ and $R_2^{a_2} - G_2^{d\frac{1\,2\,3}{3}}$ by applying —0.9 div. and —1.7 div. for the meter, and —0.8 div. and +0.5 div. for the yard, respectively.

COMPARISON OF METERS $R_1^{a_2}$, $G_1^{b_1}$, $G_2^{b_{123}}$, AND $G_2^{d_{123}}$ WITH ONE-INCH OBJECTIVE.

(1 div. = .440 μ.)

Date.	Y 61	$R_1^{a_2} - G_1^{b_1}$	$R_1^{a_2} - G_2^{b_1}$	$R_1^{a_2} - G_2^{b_2}$	$R_1^{a_2} - G_2^{b_3}$	$R_1^{a_2} - G_2^{d_1}$	$R_1^{a_2} - G_2^{d_2}$	$R_1^{a_2} - G_2^{d_3}$	$b = +4.57$ div. At 16°.67		
									$R_1^{a_2} - G_1^{b_1}$	$R_1^{a_2} - G_2^{b\frac{1\,2\,3}{3}}$	$R_1^{a_2} - G_2^{d\frac{1\,2\,3}{3}}$
1883.	°	div.		div.			div.		div.	div.	div.
July 8	21°.72	+10.0	....	+19.5	....	....	+27.6	....	—13.1	—4.5	+ 2.8
" 8	20.78	+ 3.5	....	+15.9	....	....	+23.6	....	—15.3	—3.8	+ 3.1
" 9	20.25	+ 0.8	....	+11.0	....	....	+22.0	....	—15.6	—6 3	+ 3.9
" 9	19.95	+ 1.2	....	+ 9.6	....	....	+16.4	....	—13.8	—6.3	— 0.3
" 10	19.53	— 1.3	....	+ 8.8	....	....	+10.5	....	—14.4	—5.2	— 4.4
" 10	19.49	— 0:5	+18.6	+13.1	+12.9	+18.5	+22.3	+20.4	—13.4	+1.0	+ 7.5
" 11	19.11	— 2.7	+ 8.1	+11.6	+ 9.4	+11.3	+13.3	+10 3	—13.9	—1.4	+ 0.5
" 11	19.13	— 4.9	+ 9.3	+10.8	+11.2	+18.3	+19.2	+12 7	—16.1	—1.1	+ 4.9
" 12	19.20	— 3 9	+ 8 2	+10.2	+ 7.9	+14.3	+16.0	+12.5	—15.5	—2.8	+ 2.7
" 12	19.07	— 0.3	+ 6 8	+ 8.4	+ 4·2	+12.2	+11.0	+11.9	—11.4	—4.6	+ 0.3
" 13	19.08	— 7.4	+13.2	+13.7	+14.2	+18.6	+21.3	+18.5	—18.4	+2.7	+ 8.5
" 13	19.08	— 6.8	+14.7	+15.4	+15.8	+19.9	+23.1	+19.9	—17.8	+4.3	+10.0
								Means	—14.9	—2.4	+ 3.3
									—6.6μ	—1.1μ	+ 1.5μ

Since $R_1^{a_2} + 2.8\,\mu = A$, we have

$$G_1^{b_1} \quad - 3.8\,\mu = A$$

$$G_2^{b_{\frac{123}{3}}} + 1.7\,\mu = A$$

$$G_2^{d_{\frac{123}{3}}} + 4.1\,\mu = A$$

COMPARISON OF YARDS $R_1^{a_2}$, $G_1^{b_1}$, G_2^{b123}, AND G_2^{d123}, WITH ONE-INCH OBJECTIVE.

(1 div. = .440 μ.)

Date.	Y 61	$R_1^{a_2} - G_1^{b_1}$	$R_1^{a_2} - G_2^{b_1}$	$R_1^{a_2} - G_2^{b_2}$	$R_1^{a_2} - G_2^{b_3}$	$R_1^{a_2} - G_2^{d_1}$	$R_1^{a_2} - G_2^{d_2}$	$R_1^{a_2} - G_2^{d_3}$	$b = 4.18$ div. At 16°.67		
									$R_1^{a_2} - G_1^{b_1}$	$R_1^{a_2} - G_1^{b\frac{123}{3}}$	$R_1^{a_2} - G_2^{d\frac{123}{3}}$
1883.	°	div.		div.			div.		div.	div.	div.
July 8	21.72	+8.1	....	+32.9	....	....	+40.2	....	−13.0	+10.9	+19.6
" 8	20.78	+0.0	....	+37.2	....	....	+37.9	....	−17.2	+19.1	+21.2
" 9	20.25	−1.6	....	+36.1	....	....	+35.5	....	−16.6	+20.2	+21.0
" 9	19.95	+0.1	....	+23.5	....	....	+23.0	....	−13.8	+10.7	+ 9.7
" 10	19.53	−0.3	....	+15.5	....	....	+23.2	....	−12.5	+ 5.0	+11.0
" 10	19.49	+1.0	+29.1	+27.0	+25.9	+28.5	+27.2	+31.9	−10.8	+15.5	+16.1
" 11	19.11	+0.2	+29.4	+30.3	+26.2	+33.1	+30.3	+32.2	−10.0	+18.4	+22.0
" 11	19.13	+0.5	+31.4	+33.9	+28.4	+35.6	+36.8	+34.1	− 9.8	+20.9	+25.2
" 12	19.20	−5.4	+26.1	+29.1	+22.4	+25.6	+31.3	+35.3	−16.0	+15.5	+19.0
" 12	19.07	−0.3	+24.8	+25.2	+23.7	+24.8	+28.3	+29.5	−10.3	+14.8	+18.6
" 13	19.08	−4.2	+27.0	+26.5	+26.4	+31.7	+28.3	+33.7	−14.2	+16.7	+18.2
" 13	19.08	−2.9	+26.5	+29.9	+28.1	+34.0	+30.9	+35.5	−12.9	+21.2	+23.5
								Means	−13.1	+15.7	+18.8
									− 5.8μ	+ 6.9μ	+ 8.3μ

Since $R_1^{a_2} - 1.4\,\mu = Y$, we have,

$$G_1^{b_1} \quad - 7.2\,\mu = Y$$

$$G_2^{b_{\frac{123}{3}}} + 5.5\,\mu = Y$$

$$G_2^{d_{\frac{123}{3}}} + 6.9\,\mu = Y$$

COMPARISON OF THE WHITWORTH YARD *W* WITH $R_2^{a_2}$, WITH COMPARATOR NO. 1.

(1 div. = .0000197 in.)

Date. 1881.	Time. h. m.	Fahr. °	$W - R_2^{a_2}$
April 27	5 15 A.M.	57.9	+ 51.7 div.
" 27	6 10 "	58.0	+ 52.1 div.
" 28	5 15 "	61.7	+ 20.8 div.
" 28	3 40 P.M.	67.4	— 25.9 div.
" 28	6 50 "	66.5	— 17.1 div.
" 29	5 30 A.M.	63.9	+ 7.5 div.
" 29	5 35 "	63.9	+ 8.2 div.
" 29	5 44 "	64.7	+ 11.6 div.
" 29	6 0 "	64.0	+ 8.9 div.
" 29	6 10 "	63.9	+ 7.3 div.
" 29	6 22 "	63.9	+ 15.4 div.
" 29	6 45 "	63.7	+ 5.9 div.
" 29	8 10 "	63.4	+ 7.9 div.
" 29	8 15 "	63.4	+ 10.1 div.
" 29	8 30 "	63.4	+ 10.1 div.
" 29	8 50 "	63.8	+ 10.2 div.
May 1	5 30 A.M.	81.4	—127.4 div.
" 1	8 30 "	81.6	—131.7 div.
" 1	8 40 "	81.7	—132.3 div.
" 1	9 15 "	81.8	—130.8 div.
" 1	10 20 "	81.7	—128.7 div.
" 1	11 0 "	81.7	—128.0 div.
" 1	11 45 "	81.7	—129.8 div.
" 1	11 55 "	81.7	—130.0 div.
" 1	12 45 P.M.	81.7	—128.0 div.
" 1	2 0 "	81.6	—128.4 div.
" 2	5 40 A.M.	56.1	+ 65.9 div.
" 2	6 0 "	56.1	+ 66.4 div.
" 2	6 10 "	56.1	+ 63.7 div.
" 2	9 45 "	54.8	+ 75.4 div.
" 3	5 50 "	61.0	+ 25.6 div.

EQUATIONS OF CONDITION BETWEEN W AND $R_2^{a_2}$.

$W - R_2^{a_2}$			$(\tau - 62°)$	At 62° $W - R_2^{a_2}$
+ 16.3 div.	=	a	— 0.3 b	+18.6 div.
+ 9.4 div.	=	a	— 1.8 b	+23.1 div.
—129.5 div.	=	a	—19.7 b	+20.0 div.
+ 59.4 div.	=	a	+ 5.2 b	+19.9 div.
			Mean	+20.4 div.

Normal Equations.

$$-44.4 = 4a - 16.6b \qquad b = +7.59$$

$$+2838.2 = -16.6a + 418.4b \qquad a = +20.4$$

We have, therefore, for 62° Fahr.,

$$W - R_2^{a_2} = +.000402 \text{ in.}$$

But $$R_2^{a_2} - Y = -.000008 \text{ in.}$$

Hence, $$W - .000394 \text{ in.} = Y$$

Another investigation, the details of which are not given here, gave the equation $W - .000364 \text{ in.} = Y$.

Probable Errors of Observation.

The errors of observation to which the comparisons are subject may be classified as follows: —

(*a*.) Accidental errors of observations for coincidence of micrometer line with defining lines of standard.

(*b*.) Errors due to an imperfect focus of the defining lines under the objective, and which are not included under (*a*).

(*c*.) Errors due to the failure of the thermometer to indicate the real temperature of the standards compared.

The comparisons of T^{a_2} with T^{b_1}, $R_1^{a_2}$ with $R_1^{b_2}$, and $R_1^{a_2}$ with $R_1^{d_2}$, furnish the data for the computation of probable errors of the first and second classes.

Using the formula of Peters we have for the probable error of a *single comparison*, —

$$r = .8453 \frac{[v]}{\sqrt{n(n-1)}}$$

Whence,

From $T^{a_2} - T^{b_1}$ $\qquad r = \pm 0.45\,\mu$

$R_1^{a_2} - R_1^{b_2}$ (meter) $\qquad r = \pm 0.34\,\mu$

$R_1^{a_2} - R_1^{b_2}$ (yard) $\qquad r = \pm 0.35\,\mu$

The following include errors of the class (*c*): —

From $T^{a_2} - C.\,S.$ (meter) $r = \pm 0.61\,\mu$
$T^{a_2} - R_1^{a_2}$ " $r = \pm 1.44\,\mu$
$T^{a_2} - R_2^{a_2}$ " $r = \pm 1.34\,\mu$
$C.\,S. - R_1^{a_2}$ (yard) $r = \pm 0.99\,\mu$
$C.\,S. - R_2^{a_2}$ " $r = \pm 0.49\,\mu$

For the probable error of the final results we have, —

From $T^{a_2} - T^{b_1}$ $e = \pm 0.07\,\mu$
$R_1^{a_2} - R_1^{b_2}$ (meter) $e = \pm 0.06\,\mu$
$R_1^{a_2} - R_1^{b_2}$ (yard) $e = \pm 0.06\,\mu$
$T^{a_2} - C.\,S.$ (meter) $e = \pm 0.09\,\mu$
$T^{a_2} - R_1^{a_2}$ " $e = \pm 0.22\,\mu$
$T^{a_2} - R_2^{a_2}$ " $e = \pm 0.20\,\mu$
$C.\,S. - R_1^{a_2}$ (yard) $e = \pm 0.15\,\mu$
$C.\,S. - R_2^{a_2}$ " $e = \pm 0.07\,\mu$

The only conclusion which can be safely drawn from these results is, that the errors due to temperature are between three and four times as large as the accidental errors of observation. The errors due to imperfect focus may be considered as eliminated in a long series of observations.

The writer regards the values given for the probable errors of the final results as entirely illusory. The fact that the formula for probable errors takes no account of constant errors, needs to be strongly emphasized in this connection. Errors of classes (*b*) and (*c*) are probably of this sort.

Subdivision of Standards.

The subdivisions of the various standards were made with somewhat unequal precision. In the transfers from one standard to another, the errors of subdivision are in a general way reduced; but I have thus far found it impossible to reduce them to zero when the system of corrections applied, includes a change in the entire length.

It hardly needs to be said, that one can measure the subdivisions with much greater accuracy than it is possible to obtain in making the transfers.

The following results have been obtained for the errors of subdivision of the various prototypes discussed in this paper. In bar R_2 the initial defining line is considered to be at the inch end of the bar. In all the other bars the initial line is the middle defining line of the meter and the yard. In the case of the meter the distances are reckoned as follows: —

I = distances reckoned from the middle line *towards* the cm. end.
II = distances reckoned from the middle line *away from* the cm. end.

For the yard,

I = distances reckoned *towards* the inch end.
II = distances reckoned *away from* the inch end.

The columns under the heading Σ contain the corrections reckoned from the initial line. It is to be remembered that a plus sign indicates that the measured space is too short.

SUBDIVISIONS OF $R_2^{a_2}$.

(1 div. = .504 μ.)

FEET.

	July 17.	July 18.	Mean.	Mean of all previous Observations.	Adopted Corrections.		Σ
1	−1.9 div.	−1.3 div.	−1.6 div.	−0.9 div.	−1.2 div.	−0.6 μ	−0.6 μ
2	+6.8 “	+6.4 “	+6.6 “	+4.2 “	+5.4 “	+2.8 μ	+2.2 μ
3	−4.8 “	−5.4 “	−5.1 “	−3.3 “	−4.2 “	−2.2 μ	+0.0 μ

THREE-INCH SPACES OF THE FIRST FOOT.

	July 15.	July 15.	July 17.	July 18.	July 19.	July 20.	July 21.	Means.		Σ
1	−6.6 div.	−5.4 div.	−3.2 div.	−2.8 div.	−3.6 div.	−4.3 div.	−4.1 div.	−4.3 div.	= −2.2 μ	−2.2 μ
2	+2.9 “	+1.0 “	−1.3 “	+0.3 “	−1.0 “	+0.9 “	+0.9 “	+0.2 “	= +0.1 μ	−2.1 μ
3	−3.0 “	−2.3 “	−1.5 “	−3.6 “	−2.1 “	−3.4 “	−2.2 “	−2.6 “	= −1.3 μ	−3.4 μ
4	+6.8 “	+8.6 “	+6.0 “	+6.4 “	+6.7 “	+5.7 “	+5.5 “	+6.8 “	= +3.5 μ	+0.1 μ

INCHES OF THE FIRST THREE-INCH SPACE.

	July 17.	July 18.	July 19.	Mean.			Σ
1	−0.9 div.	−0.5 div.	+0.0 div.	−0.5 div.	=	−0.2 μ	−0.2 μ
2	+1.6 “	+0.8 “	+0.8 “	+1.1 “	=	+0.5 μ	+0.3 μ
3	−0.7 “	−0.3 “	−0.8 “	−0.6 “	=	−0.3 μ	+0.0 μ

For the subdivisions, near the edge of R_2 we have: —

METER.

Halves.

I = —0.7 μ
II = +0.7 μ

Dm. Spaces.

	Σ
I = —4.4 μ	—4.4 μ
II = —0.4 μ	—4.8 μ
III = +1.2 μ	—3.6 μ
IV = +3.4 μ	—0.2 μ
V = +0.2 μ	+0.0 μ

Cm. Spaces.

	Σ
I = —3.4 μ	—3.4 μ
II = +1.9 μ	—1.5 μ
III = +0.6 μ	—0.9 μ
IV = —1.1 μ	—2.0 μ
V = —0.4 μ	—2.4 μ
VI = +0.1 μ	—2.3 μ
VII = —0.6 μ	—2.9 μ
VIII = +0.0 μ	—2.9 μ
IX = +0.4 μ	—2.5 μ
X = +2.6 μ	+0.1 μ

YARD.

Halves.

I = +1.0 μ
II = —1.0 μ

Six-Inch Spaces.

	Σ
I = +4.0 μ	+4.0 μ
II = —3.7 μ	+0.3 μ
III = —0.3 μ	+0.0 μ

Inch Spaces.

	Σ
I = +0.1 μ	+0.1 μ
II = +0.2 μ	+0.3 μ
III = +0.3 μ	+0.6 μ
IV = —0.4 μ	+0.2 μ
V = +2.0 μ	+2.2 μ
VI = —2.2 μ	+0.0 μ

SUBDIVISIONS OF $R_1^{a_2}$.

METER.

Halves.

I = +4.3 μ
II = —4.3 μ

Dm. Spaces.

	Σ
I = +3.4 μ	+3.4 μ
II = +0.5 μ	+3.9 μ
III = —0.3 μ	+3.6 μ
IV = —2.6 μ	+1.0 μ
V = —1.0 μ	+0.0 μ

Five Cm. Spaces.

I = —0.1 μ
II = +0.1 μ

YARD.

Halves.

I = +3.8 μ
II = —3.8 μ

Six-Inch Spaces.

	Σ
I = —2.1 μ	—2.1 μ
II = +0.0 μ	—2.1 μ
III = +2.1 μ	+0.0 μ

Inch Spaces.

	Σ
I = +0.6 μ	+0.6 μ
II = —0.9 μ	—0.3 μ
III = +0.0 μ	—0.3 μ
IV = +0.1 μ	—0.2 μ
V = +1.2 μ	+1.0 μ
VI = —1.0 μ	+0.0 μ

Cm. Spaces.

		Σ
I	= −2.2 μ	−2.2 μ
II	= +1.8 μ	−0.4 μ
III	= −1.3 μ	−1.7 μ
IV	= +1.1 μ	−0.6 μ
V	= +0.6 μ	+0.0 μ

SUBDIVISIONS OF G_1.

METER.

Halves.

	G_1^{a2}	G_1^{b1}
I	= +1.5 μ	+1.2 μ
II	= −1.5 μ	−1.2 μ

Dm. Spaces.

		Σ		Σ
I	= +1.1 μ	+1.1 μ	+0.4 μ	+0.4 μ
II	= −2.3 μ	−1.2 μ	−0.9 μ	−0.5 μ
III	= −0.2 μ	−1.4 μ	+0.3 μ	−0.2 μ
IV	= −0.7 μ	−2.1 μ	+1.4	−1.2 μ
V	= +2.1 μ	+0.0 μ	+1.2 μ	+0.0 μ

Cm. Spaces.

		Σ		Σ
I	= +0.2 μ	+0.2 μ	−1.7 μ	+1.7 μ
II	= +0.4 μ	+0.6 μ	−3.1 μ	−1.4 μ
III	= −0.6 μ	+0.0 μ	+1.4 μ	+0.0 μ
IV	= +1.0 μ	+1.0 μ	+0.3 μ	+0.3 μ
V	= −1.0 μ	+0.0 μ	−0.3 μ	+0.0 μ

Five Cm. Spaces.

I	= −1.1 μ	−3.7 μ
II	= +1.1 μ	+3.7 μ

YARD.

Halves.

	G_1^{a2}	G_1^{b1}
I	= −1.7 μ	−1.8 μ
II	= +1.7 μ	+1.8 μ

Six-Inch Spaces.

		Σ		Σ
I	= −0.2 μ	−0.2 μ	+1.4 μ	+1.4 μ
II	= −0.4 μ	−0.6 μ	−1.9 μ	−0.5 μ
III	= +0.6 μ	+0.0 μ	+0.4 μ	+0.1 μ

Inch Spaces.

		Σ		Σ
I	= −1.3 μ	−1.3 μ	−1.0 μ	−1.0 μ
II	= +1.1 μ	−0.2 μ	−0.7 μ	−1.7 μ
III	= −0.5 μ	−0.7 μ	−0.1 μ	−1.8 μ
IV	= +0.2 μ	−0.5 μ	−2.2 μ	−4.0 μ
V	= +0.5 μ	+0.0 μ	+3.1 μ	−0.9 μ
VI	= +0.0 μ	+0.0 μ	+1.0 μ	+0.1 μ

SUBDIVISIONS OF G_2.

METER.

Halves.

	G_2^{a2}	G_2^{b2}	G_2^{d2}
I	= +3.2μ	+1.7μ	−1.1μ
II	= −3.2μ	−1.7μ	+1.1μ

Dm. Spaces.

		Σ		Σ		Σ
I	= +2.2μ	+2.2μ	+1.3μ	+1.3μ	−3.3μ	−3.3μ
II	= −2.5μ	−0.3μ	−1.3μ	+0.0μ	+0.1μ	−3.2μ
III	= −1.2μ	−1.5μ	+1.4μ	+1.4μ	+2.0μ	−1.2μ
IV	= +1.2μ	−0.3μ	−2.8μ	−1.4μ	−0.2μ	−1.4μ
V	= +0.3μ	+0.0μ	+1.5μ	+0.1μ	+1.4μ	+0.0μ

YARD.

Halves.

	G_2^{a2}	G_2^{b2}	G_2^{d2}
I	= +4.0μ	+1.7μ	+1.4μ
II	= −4.0μ	−1.7μ	−1.4μ

Six-Inch Spaces.

		Σ		Σ		Σ
I	= −0.4μ	−0.4μ	+2.6μ	+2.6μ	−1.7μ	−1.7μ
II	= +0.0μ	−0.4μ	−1.3μ	+1.3μ	+0.2μ	−1.5μ
III	= +0.4μ	+0.0μ	−1.3μ	+0.0μ	+1.5μ	+0.0μ

Cm. Spaces.

		Σ		Σ		Σ
I =	−0.1μ	−0.1μ	+1.7μ	+1.7μ	+2.0μ	+2.0μ
II =	+0.2μ	+0.1μ	−2.9μ	−1.2μ	−2.3μ	−0.3μ
III =	−0.1μ	+0.0μ	+0.9μ	−0.3μ	+0.4μ	+0.1μ
IV =	+0.4μ	+0.4μ	−0.2μ	−0.5μ	+0.2μ	+0.3μ
V =	−0.4μ	+0.0μ	+0.5μ	+0.0μ	−0.2μ	+0.1μ

Inch Spaces.

		Σ		Σ		Σ
I =	−1.3μ	−1.3μ	−4.5μ	−4.5μ	−4.2μ	−4.2μ
II =	+1.1μ	−0.2μ	−0.1μ	−4.6μ	−0.2μ	−4.4μ
III =	−0.5μ	−0.7μ	+3.6μ	−1.0μ	+4.0μ	−0.4μ
IV =	+0.3μ	−0.4μ	−1.6μ	−2.6μ	−2.1μ	−2.5μ
V =	+1.3μ	+0.9μ	+3.3μ	+0.7μ	+4.2μ	+1.7μ
VI =	−0.9μ	+0.0μ	−0.7μ	+0.0μ	−1.7μ	+0.0μ

Five Cm. Spaces.

I =	−0.8μ	−3.7μ	−4.8μ
II =	+0.8μ	+3.7μ	+4.8μ

Equation between the Imperial Yard and the Metre des Archives.

The writer presented to the Montreal meeting of the American Association for the Advancement of Science, in 1882, a paper in which the following relation was announced: —

$$\text{Imperial Yard} + 3.37015 \text{ inches} = \text{Metre des Archives}.$$

I stated at that time, however, with reference to this relation, that for very obvious reasons I should not like to be held to a very strict account with reference to the last decimal figure given, or even to the last two decimal figures.

The problem consists of two parts: —

First, the determination of the relation at 62° F. or 16°.67 C. between the particular yard and meter defined by $R_2{}^{a}{}_{2}$, and the original standards from which these units were derived.

Second, the measurement of the space 3.370+ inches.

Let $M =$ the true value of the meter $R_2^{a_2}$, expressed in terms of the Metre des Archives.

$Y' =$ the true value of the yard $R_2^{a_2}$ expressed in terms of the Imperial Yard.

$X = R_2^{a_2}$ (meter) — $R_2^{a_2}$ (yard).

Then $$X = M - Y'.$$

In the investigation of 1882, a space of four inches was laid off upon a short bar designated B, having the same composition as R_2. This space was subdivided to inches. The third inch was subdivided to tenths of an inch, and the seventh tenth was subdivided to hundredths of an inch. The following relations between the subdivisions of $R_2^{a_2}$ and B were then determined.

Since the investigation of 1882, it has been possible to make the relation between $R_2^{a_2}$ and the original units more secure through the medium of the yard and meter *C. S.* In the present discussion it was thought better to vary the method of determining the value of X.

Let $x =$ the three-inch space beyond the limits of the yard $R_2^{a_2}$.

$y =$ the distance between the defining line of this space and the defining line at this end of the meter $R_2^{a_2}$.

Then

$$M = Y' + x + y.$$

The value of x was determined by comparing this space with the four three-inch spaces composing the first foot of $R_2^{a_2}$. This was very easily and expeditiously done by setting the stops of the comparator at a distance approximately equal to x, and then comparing each space with this constant distance.

For the measurement of the distance y, a space of two inches was laid off upon a short bronze bar with subdivisions to half-inches. The third half-inch is subdivided into five equal parts, and the third subdivision is again subdivided into ten equal parts. The following relations were found between these subdivisions.

Half-Inch Spaces.

	July 15.	July 17.	July 19.	July 19.	July 20.	July 21.	July 22.	Mean.			Σ
I. =	−4.4div.	−2.1div.	−2.5div.	−2.8div.	−2.8div.	+0.4div.	−1.8div.	−2.3div.	=	−1.2μ	−1.2μ
II. =	+0.1 "	+1.8 "	+3.5 "	+3.5 "	+2.9 "	+0.5 "	+2.8 "	+2.1 "	=	+1.1μ	−0.1μ
III. =	+2.5 "	+2.2 "	−2.1 "	−1.7 "	−1.1 "	−1.3 "	−1.6 "	−0.5 "	=	−0.2μ	−0.3μ
IV. =	+1.8 "	−1.9 "	+1.1 "	+1.0 "	+1.0 "	+0.2 "	+0.7 "	+0.6 "	=	+0.3μ	+0.0μ

One-Tenth Inch Spaces.

	July 14.	July 15.	July 17.	July 20.	July 21.	Means.			Σ
I. =	+2.9 div.	+1.5 div.	+2.3 div.	+2.1 div.	+1.7 div.	+2.1 div.	=	+1.1 μ	+1.1 μ
II. =	+1.8 "	+0.6 "	−0.4 "	+0.6 "	+0.1 "	+0.5 "	=	+0.2 μ	+1.3 μ
III. =	−0.9 "	−1.3 "	+0.2 "	−1.0 "	−1.0 "	−0.8 "	=	−0.4 μ	+0.9 μ
IV. =	−1.0 "	+0.7 "	−0.9 "	−1.1 "	+0.7 "	−0.3 "	=	−0.1 μ	+0.8 μ
V. =	−2.8 "	−1.6 "	−1.0 "	−0.5 "	−1.5 "	−1.5 "	=	−0.8 μ	+0.0 μ

One-Hundredth Inch Spaces.

	July 14.	July 15.	July 17.	July 21.	Means.			Σ
I. =	−1.7 div.	− 1.3 div.	+0.5 div.	+1.2 div.	−0.3 div.	=	−0.2 μ	−0.2 μ
II. =	−3.1 "	− 6.4 "	−4.5 "	−5.9 "	−4.5 "	=	−2.3 μ	−2.5 μ
III. =	+3.7 "	+ 3.6 "	+4.6 "	+4.3 "	+4.0 "	=	+2.0 μ	−0.5 μ
IV. =	+0.9 "	+ 1.1 "	+0.9 "	−0.7 "	+0.5 "	=	+0.3 μ	−0.2 μ
V. =	−1.4 "	− 0.3 "	−0.5 "	+0.4 "	−0.5 "	=	−0.2 μ	−0.4 μ
VI. =	−8.0 "	− 8.2 "	−9.5 "	−7.9 "	−8.4 "	=	−4.3 μ	−4.7 μ
VII. =	+8.5 "	+11.4 "	+8.6 "	+8.7 "	+9.3 "	=	+4.8 μ	+0.1 μ
VIII. =	+0.6 "	+ 2.5 "	+1.3 "	+1.0 "	+1.3 "	=	+0.6 μ	+0.7 μ
IX. =	+0.3 "	+ 0.5 "	−2.4 "	−1.4 "	−0.8 "	=	−0.4 μ	+0.3 μ
X. =	+0.2 "	− 3.0 "	+1.0 "	+0.0 "	−0.5 "	=	−0.3 μ	+0.0 μ

SUBDIVISIONS OF $R_2^{a_2}$.

Feet.

		Σ
I	$-0.4\,\mu$	$-0.4\,\mu$
II	$+1.6\,\mu$	$+1.2\,\mu$
III	$-1.2\,\mu$	$+0.0\,\mu$

Six-Inch Spaces of First Foot.

I $= -2.1\,\mu$
II $= +2.1\,\mu$

Inch Spaces of the First Six Inches.

		Σ
I	$= -0.7\,\mu$	$-0.7\,\mu$
II	$= +1.6\,\mu$	$+0.9\,\mu$
III	$= +0.2\,\mu$	$+1.1\,\mu$
IV	$= -0.5\,\mu$	$+0.6\,\mu$
V	$= -0.7\,\mu$	$-0.1\,\mu$
VI	$= +0.1\,\mu$	$+0.0\,\mu$

Four-Inch Spaces of First Foot.

		Σ
I	$= -0.1\,\mu$	$-0.1\,\mu$
II	$= -2.8\,\mu$	$-2.9\,\mu$
III	$= +2.9\,\mu$	$+0.0\,\mu$

SUBDIVISIONS OF B.

Inches.

		Σ
I	$= +0.5\,\mu$	$+0.5\,\mu$
II	$= +0.1\,\mu$	$+0.6\,\mu$
III	$= -2.2\,\mu$	$-1.6\,\mu$
IV	$= +1.6\,\mu$	$+0.0\,\mu$

Tenths of Third Inch.

		Σ
I	$= +0.3\,\mu$	$+0.3\,\mu$
II	$= +0.2\,\mu$	$+0.5\,\mu$
III	$= +0.9\,\mu$	$+1.4\,\mu$
IV	$= -1.3\,\mu$	$+0.1\,\mu$
V	$= -0.2\,\mu$	$-0.1\,\mu$
VI	$= +0.2\,\mu$	$+0.1\,\mu$
VII	$= -0.4\,\mu$	$-0.3\,\mu$
VIII	$= +0.2\,\mu$	$-0.1\,\mu$
IX	$= -0.3\,\mu$	$-0.4\,\mu$
X	$= +0.4\,\mu$	$+0.0\,\mu$

Hundredths of an Inch.

	Σ
$+0.1\,\mu$	$+0.1\,\mu$
$+0.0\,\mu$	$+0.1\,\mu$
$+0.0\,\mu$	$+0.1\,\mu$
$-0.2\,\mu$	$-0.1\,\mu$
$-0.1\,\mu$	$-0.2\,\mu$
$+0.3\,\mu$	$+0.1\,\mu$
$+0.1\,\mu$	$+0.2\,\mu$
$-0.1\,\mu$	$+0.1\,\mu$
$-0.2\,\mu$	$-0.1\,\mu$
$+0.1\,\mu$	$+0.0\,\mu$

The value of X expressed in the same unit as Y was found to be 3.370319 inches.

Up to this point in the investigation, the following relations had been found:—

$$R_2^{a_2}\,(\text{meter}) - 2.6\,\mu = A,$$

$$R_2^{a_2}\,(\text{yard}) + 1.6\,\mu = Y,$$

whence

$$1.0000026\ A = [35.999934 + 3.370319]\ \text{inches},$$

and

$$A = 39.37015\ \text{inches}.$$

Comparison of 2 Inches of Scale B with the first 2 Inches of $R_2^{a_2}$.

From observations of July 21,

$$B + 1.9 \text{ div.} = \text{first 2 inches of } R_2^{a_2}.$$

From observations of July 22,

$$B + 1.8 \text{ div.} = \text{first 2 inches of } R_2^{a_2}.$$

The following relations for x and y were found, x being expressed in terms of the first foot of $R_2^{a_2}$ divided by 4, and y in terms of line 37 of the scale B.

	x	y
July 15	3 inches +13.2 div.	+2.9 div.
“ 15	“ +19.1 “	+2.8 “
“ 17	“ +17.4 “	+5.0 “
“ 18	“ +16.9 “	+4.0 “
“ 19	“ +16.3 “	+2.2 “
“ 20	“ +14.3 “	+2.6 “
“ 21	“ +16.2 “	+4.5 “
“ 22	“ +16.3 “	+2.1 “
Means	3 inches +16.3 div. = 3.000321 inches.	+3.3 div. = .000065 inch.

Expressed in terms of Y, x becomes 3.000327 inches.
and $x + y$ expressed in the same unit becomes 3.000392 “

This quantity is now to be corrected by the amount of the error of line 37 of the third half-inch of the scale B. We have,

$$2 \text{ inches of } B + [1.9 + 0.6 - 0.2] \text{ div.} = \frac{1}{18} Y.$$

The correction to line 37 of the third inch of scale B is, therefore,

$$2 \text{ inches} - \Big[1.7 + [1.8 - 1.0 + 0.2]\Big] \text{ div.} = \frac{1}{72} Y.$$

Expressed in terms of Y, we have, finally,

$$x + y = 3.370339 \text{ inches.}$$

From the observations of 1882,

$$x + y = 3.370319 \text{ inches.}$$

Adopting the mean between these values, we have

$$M + x + y = [36.999992 + 3.370329] \text{ inches.}$$

We have therefore, finally,

$$1.0000013\, A = 39.370321 \text{ inches,}$$

and

$$A = \mathbf{39.37027 \text{ inches.}}$$

XXIII.

ON THE REDUCTION OF DIFFERENT STAR CATALOGUES TO A COMMON SYSTEM.

By William A. Rogers.

Presented May 9th, 1883.

The communication of Professor Safford, in the March number of the Monthly Notices of the Royal Astronomical Society, cites in a forcible way some of the causes of discrepancies in stellar co-ordinates to which too little attention has hitherto been paid. Incidentally he refers to the class of errors which are introduced in the computation of the systematic corrections necessary to reduce different catalogues to a common system. Without this reduction it is impossible to obtain the element proper motion with the degree of precision which modern observations call for.

It is unfortunate that this necessity exists, since considerable uncertainty must always remain in the determination of these corrections. One of the serious demands of instrumental astronomy at the present time is the independent determination at a few widely separated observatories of all the elements which define stellar positions, without direct reference to any assumed fundamental system. The Catalogue of A. G. Publication XIV. by Dr. Auwers is probably more nearly free from systematic errors than any hitherto constructed; but the independent researches of Professor Boss show that the fundamental observations in declination from about 1815 to 1845 differ as a system from the Auwers-Bradley system by an amount which cannot be neglected.

Since it is obviously impracticable to redetermine the instrumental constants with which the different catalogues to be compared have been constructed, by a direct reference to the fundamental system to which they are to be referred, and with these constants to deduce new co-ordinates, we must seek the best method of deriving the systematic corrections required. The general tendency of modern practice is towards the graphic method, in preference to a rigid analytical determination. But the difficulty exists that computers do not agree in the details of the graphical methods employed, and hence with the same data different results are obtained. It is the common practice to draw the curves which represent the residuals in right ascension with this function as the horizontal argument, but there are several catalogues in which the residuals $\Delta\alpha$ are functions of both the right ascension and of the declination.

In the choice of any method, it is obvious that preference must be given to that in which the residuals $\Delta\alpha$ and $\Delta\delta$ are reduced to a minimum, *whatever the order or the limits of the groups into which they may be divided.* It is believed that this will be best accomplished by the use of what, for the lack of a better term, may be described as double-argument curves.

Suppose, for example, that all the residuals in right ascension for a given catalogue which fall within the limits of the groups in declination $-10° \ldots +0°$, $+0° \ldots +10°$, $+10° \ldots +15°$, etc., are arranged in groups in the order of right ascension. Since the values of the residuals may be assumed to be true (nearly) for the mean of the groups into which they are divided, whether the argument be the right ascension or the declination, it is obvious that we can choose either the values which are functions of the right ascension, or those which depend on the declination, at pleasure, in the construction of the graphic curves. But whichever is chosen, the residuals derived from the constructed curves no longer represent the mean values which correspond to the other argument; that is, the values which are functions of one argument are derived from the same curve, while those which are functions of the other argument are derived from different curves.

The character of these double-argument functions are illustrated in the following (fictitious) example.

$\Delta\alpha$

TABLE I.

	—10° . . +0°	+0° . . +10°	+10° . . +20°	+20° . . +30°	+30° . . +40°	+40° . . +50°	+50° . . +60°	+60° . . +70°
h. h.	s.	s.	s.	s.	s.	s.	s.	s.
0.. 2	+.050	+.129	+.175	+.232	+.323	+.338	+.413	+.427
2.. 4	+.077	+.076	+.118	+.213	+.218	+.300	+.300	+.334
4.. 6	+.031	+.064	+.110	+.118	+.193	+.194	+.214	+.216
6.. 8	+.043	+.058	+.050	+.088	+.077	+.112	+.100	+.125
8..10	+.028	+.028	+.044	+.047	+.064	+.058	+.061	+.062
10..12	+.006	+.013	+.007	+.013	+.017	+.015	+.016	+.017
12..14	—.007	—.019	—.009	—.021	—.018	—.030	—.034	—.037
14..16	—.008	—.041	—.058	—.038	—.082	—.085	—.090	—.100
16..18	—.041	—.049	—.066	—.080	—.087	—.115	—.140	—.140
18..20	—.030	—.083	—.118	—.091	—.148	—.150	—.190	—.213
20..22	—.069	—.097	—.113	—.138	—.163	—.200	—.225	—.250
22..24	—.068	—.124	—.150	—.150	—.215	—.230	—.265	—.300

These residuals may be considered as representing the true deviation from the normal places, either at 1^h, 3^h, 5^h, etc., or at —5°, +5°, +15°, etc.

If the right ascension is assumed as the argument, we shall have from the curves represented by $\Delta\alpha$ the following:—

TABLE II.

	—5°	+5°	+15°	+25°	+35°	+45°	+55°	+65°
h.	s.	s.	s.	s.	s.	s.	s.	s.
1	+.072	+.106	+.163	+.235	+.290	+.350	+.415	+.425
3	+.062	+.087	+.130	+.180	+.232	+.280	+.300	+.322
5	+.050	+.072	+.097	+.130	+.170	+.200	+.207	+.220
7	+.037	+.053	+.060	+.087	+.112	+.130	+.130	+.128
9	+.027	+.033	+.033	+.047	+.056	+.067	+.067	+.060
11	+.013	+.014	+.014	+.016	+.010	+.018	+.018	+.011
13	—.009	—.006	—.007	—.018	—.030	—.032	—.037	—.040
15	—.020	—.026	—.025	—.047	—.060	—.079	—.087	—.090
17	—.033	—.045	—.045	—.073	—.093	—.117	—.137	—.143
19	—.048	—.070	—.071	—.105	—.123	—.157	—.186	—.205
21	—.060	—.100	—.120	—.133	—.150	—.197	—.226	—.257
23	—.077	—.127	—.127	—.160	—.165	—.233	—.260	—.306

The values in the horizontal columns, having been derived from different curves, no longer sustain the relation which existed in the corresponding values of Table I. They may be connected symmetrically by drawing a series of smooth curves with the declination for the argument, as shown in Table III.

TABLE III.

	—5°	+5°	+15°	+25°	+35°	+45°	+55°	+65°
h.	s.	s.	s.	s.	s.	s.	s.	s.
1	+.053	+.112	+.170	+.228	+.288	+.347	+.407	+.452
3	+.048	+.092	+.138	+.182	+.228	+.270	+.307	+.333
5	+.044	+.075	+.103	+.131	+.168	+.196	+.213	+.228
7	+.035	+.054	+.072	+.092	+.109	+.127	+.130	+.130
9	+.026	+.036	+.041	+.050	+.054	+.060	+.066	+.070
11	+.013	+.013	+.012	+.012	+.013	+.013	+.013	+.012
13	—.007	—.008	—.013	—.022	—.028	—.036	—.040	—.041
15	—.023	—.027	—.036	—.048	—.067	—.077	—.087	—.097
17	—.041	—.047	—.059	—.077	—.098	—.120	—.133	—.145
19	—.057	—.068	—.083	—.103	—.126	—.157	—.180	—.200
21	—.076	—.090	—.108	—.132	—.157	—.194	—.227	—.267
23	—.107	—.117	—.139	—.167	—.190	—.220	—.264	—.317

Nearly the same results should be reached by starting with the declination for the argument, using the values of *Δα* in the horizontal columns. With the corrected values thus obtained, curves representing these residuals were drawn with the right ascension as the argument.

Proceeding in this order, we obtain finally the values of *Δα* given in

TABLE IV.

	—5°	+5°	+15°	+25°	+35°	+45°	+55°	+65°
h.	s.	s.	s.	s.	s.	s.	s.	s.
1	+.050	+.117	+.185	+.245	+.310	+.355	+.388	+.418
3	+.043	+.092	+.145	+.194	+.238	+.268	+.296	+.316
5	+.036	+.073	+.109	+.138	+.168	+.188	+.208	+.224
7	+.030	+.058	+.073	+.086	+.098	+.110	+.126	+.127
9	+.025	+.033	+.038	+.040	+.043	+.047	+.050	+.052
11	+.013	+.012	+.009	+.006	+.000	—.004	—.006	—.007
13	—.004	—.009	—.016	—.023	—.037	—.042	—.047	—.054
15	—.019	—.028	—.040	—.053	—.067	—.080	—.098	—.120
17	—.036	—.048	—.064	—.080	—.099	—.118	—.136	—.153
19	—.054	—.070	—.088	—.107	—.134	—.160	—.183	—.200
21	—.066	—.090	—.114	—.137	—.167	—.188	—.213	—.240
23	—.086	—.114	—.142	—.166	—.198	—.228	—.264	—.300

It will be seen that there is a subtantial agreement between the values in Tables III. and IV. These values have been derived directly from the curves, and no attempt has been made to smooth them by the differences. Inasmuch as it will rarely, if ever, happen that the periodicity in both directions is as great as in this example, the agreement of the values may be taken as an index of the magnitude of the errors likely to be introduced through the process of drawing the curves. It will not escape attention, that in this case, at least, the values in the two tables differ systematically at certain points. It is the experience of the writer that the periodicity thus introduced sometimes amounts to one fourth or one fifth as much as the systematic deviation of the catalogue compared from the normal system.

In the paper on "A Comparison of the Harvard College Observatory Catalogue of Stars for 1875.0 with the Fundamental Systems of Auwers, Safford, Boss, and Newcomb," the method here described has been essentially followed. But in order to reduce the magnitude of the residuals with which we have to deal, the computed corrections depending on both the right ascension and the declination were subtracted from the original residuals, and the values of $d\Delta\alpha$ and $d\Delta\delta$ which remain were treated in the way above described, giving the corrections found in Table III. Notwithstanding the criticism of Professor Safford that this method is unusual, I must maintain that it gives nearer approximations to the true corrections than can be obtained in any other way.

Professor Safford has given an exhaustive discussion of the most probable values of the right ascensions of a list of stars given in the Memoir to which reference has been made. This discussion involves, however, a knowledge of the systematic errors of the catalogues compared. It will be interesting to compare with his results the final results of the Harvard College observations of these stars, in which there is a direct dependence upon the system of Publication XIV., and in which, therefore, there is no need of applying corrections for a systematic deviation from the assumed system. An experience of thirteen years has shown that the Harvard College Meridian Circle can be relied upon to follow very closely the fundamental system chosen in a series of differential observations.

Two stars of the list have erroneous values in the final catalogue.

For β Lyræ, the right ascension should read $18^h\ 45^m\ 27^s.851$, instead of $27^s.774$.

In the case of v Pegasi, there is a misprint in the volume for 1872 of $23^h\ 18^m\ 59^s.374$ for $59^s.574$.

By a reference to the original manuscripts it is found that both of these errors had been corrected, but by some mistake the corrections were not made on the sheets prepared for the printer. There were about a dozen errors of this kind, but all of them seem to have been corrected in printing except these two.

For the remaining stars the deviations from the positions given in Publication XIV. are given below, except for the star 1 H. Draconis, where the comparison is made with the place derived from the correction given by Auwers in A. G. 1879, p. 2. These results are given in advance of publication, with the permission of Professor Pickering, the Director of the Observatory.

Year of Obs.	H. C. O. *minus* Pub. XIV.
Br. 6. $\alpha = 0^h\ 9^m$ $\delta = +76^\circ.3$	
	s.
1871	—.04
"	+.00
"	+.11
"	+.18
1872	+.05
"	—.11
"	+.07
"	+.11
1873	+.11
"	+.19
"	+.12
"	+.11
"	+.33
"	+.14
"	+.30
"	—.05
1874	+.11
"	+.00
"	+.14
"	+.17
"	+.41
1875	+.49
"	+.31
1876	+.02
"	—.11
"	+.09
"	+.26
1877	+.12
"	+.05
"	+.19
"	+.51
"	+.47
"	+.42
"	+.29
"	+.14
η Cassiop. $\alpha = 0^h\ 42^m$ $\delta = +57^\circ.2$	
	s.
1870	+.01
"	+.03
"	—.02
1871	+.06
"	—.01
"	+.02
"	+.18
"	+.07
"	+.05
1872	+.03
"	+.12
"	+.11
1873	+.18
"	+.13
"	+.13
"	+.14
"	+.12
1874	+.03
"	+.11
"	+.02
"	+.10
"	+.15
"	+.01
"	—.03
"	+.08
1876	+.05
"	+.07
"	+.08
"	+.08
1877	+.09
"	+.12
"	+.17
"	—.01
"	+.04
"	+.17
"	+.03
36 Camelop. $\alpha = 6^h\ 0^m$ $\delta = +65^\circ.7$	
	s.
1871	+.17
"	+.08
"	—.03
1874	+.05
"	+.01
1876	+.07
"	+.10
"	+.15
"	+.00
1 H. Draconis. $\alpha = 9^h\ 19^m$ $\delta = +81^\circ.9$	
	s.
1871 U.C.	+.25
"	+.17
1871 L.C.	+.07
"	+.14
"	+.18
"	+.01
"	—.06
"	+.12
"	+.19
"	+.19
"	+.15
"	+.00
"	+.04
"	+.03
1872 U.C.	+.14
"	—.09
"	+.26
"	—.02
"	+.19
"	+.52
"	+.23
"	—.11
"	+.17
1873 U.C.	+.25
1873 L.C.	+.15
"	+.28
"	—.01
"	+.33
"	+.34
"	+.35
1874 L.C.	+.25
"	+.34
"	+.42
"	+.49
1875 U.C.	+.38
"	+.28
1875 U.C.	+.19
"	+.22
"	+.31
"	+.52
"	[+.80]
"	+.18
1876 U.C.	+.55
"	+.06
"	+.01
1877 U.C.	+.69
"	—.26
"	+.35
"	+.11
"	+.28
1878 U.C.	+.12
"	+.17
"	+.63
"	+.03
"	+.21
Gr. 2164. $\alpha = 14^h\ 48^m$ $\delta = +59^\circ.8$	
	s.
1871	+.01
"	+.18
"	—.06
"	+.08
"	+.04
"	+.02
"	+.05
"	+.06
"	—.06
1872	+.02
"	+.03
"	—.03
"	+.04
1873	+.05
"	—.03
"	—.06
"	—.01
"	—.06
"	—.11
"	—.10
"	—.12
"	—.28
1876	+.02

Year of Obs.	H. C. O. *minus* Pub. XIV.
θ Draconis α = 16h 0m δ = +58°.9	
	s.
1871	—.20
"	—.14
"	—.08
"	—.08
"	—.07
"	—.19
"	—.12
1872	—.07
"	—.06
"	—.09
"	—.10
"	—.04
"	—.11
1873	—.12
"	—.09
"	—.04
"	—.10
"	—.07
"	—.13
"	—.21
1874	+.08
"	—.11
"	—.01
"	+.00
"	+.08
"	—.01
"	+.00
"	+.00
"	+.02
"	—.18
"	+.03
1875	—.08
"	+.27
"	—.18
"	—.12
"	—.04
1876	—.10
"	—.35
"	—.04
"	—.28
"	—.14
"	—.07
η Draconis. α = 16h 22m δ = +61°.8	
	s.
1871	+.03
"	—.21
"	—.17
1872	—.17
"	—.18
"	—.12
"	—.20
"	—.15
"	—.20
"	—.16
"	—.06
1873	+.12
"	—.13
"	—.14
"	—.15
"	—.08
"	—.39
1874	—.13
"	—.32
"	—.11
"	—.13
"	—.13
"	—.11
"	—.14
"	—.16
"	—.10
"	—.07
"	—.09
"	—.24
"	—.18
"	—.05
"	—.08
"	—.29
"	—.08
"	—.02
1875	—.08
"	—.18
"	—.16
"	—.19
"	—.19
"	—.24
"	—.25
"	—.02
	s.
1875	—.16
"	—.13
"	—.15
1876	—.28
"	—.16
"	—.24
"	—.40
"	—.13
1877	—.24
"	—.28
"	—.05
"	—.30
"	—.36
1878	—.10
"	—.17
"	—.08
"	—.34
"	—.23
"	—.25
"	—.03
"	—.21
Gr. 2377. α = 16h 43m δ = +57°.0	
	s.
1871	+.09
"	—.11
"	—.10
"	—.08
"	—.12
"	—.13
1872	—.12
"	—.08
"	—.08
"	—.17
"	—.11
"	—.07
"	—.20
"	—.10
"	—.06
1873	—.16
"	—.25
"	—.06
"	—.03
"	—.08
"	—.20
	s.
1874	+.04
"	+.02
"	+.05
"	—.11
"	—.09
"	—.10
"	—.07
"	—.15
"	+.04
"	—.13
1875	—.10
"	—.12
"	—.10
"	—.06
"	—.17
"	—.15
"	—.13
1876	+.03
"	—.15
"	—.13
"	—.18
"	—.17
"	—.12
Gr. 2900. α = 19h 29m δ = +79°.4	
	s.
1871	+.34
1872	+.20
"	+.07
"	+.07
1873 U.C.	+.11
"	+.02
"	+.16
"	—.04
"	+.04
"	+.17
"	—.02
"	+.24
"	+.15
"	+.37
"	+.09
1874	+.12
"	+.34
"	+.38
"	+.20
"	+.11

Collecting the results for each year we have: —

Br. 6.		
Year.	$\Delta\alpha$	No. Obs.
	s.	
1871	+.062	4
1872	+.030	4
1873	+.156	8
1874	+.166	5
1875	+.400	2
1876	+.065	4
1877	+.274	8

η Cassiop.		
	s.	
1870	+.007	3
1871	+.062	6
1872	+.087	3
1873	+.140	5
1874	+.059	8
1876	+.070	4
1877	+.087	7

36 Camelop.		
	s.	
1871	+.073	3
1874	+.030	2
1876	+.080	4

1 H. Draconis.		
Year.	$\Delta\alpha$	No. Obs.
	s.	
1871	+.106	14
1872	+.143	9
1873	+.242	7
1874	+.375	4
1875	+.297	7
1876	+.207	3
1877	+.234	5
1878	+.232	5

Gr. 2164.		
	s.	
1871	+.036	9
1872	+.015	4
1873	—.080	9
1876	+.020	1

θ Draconis.		
	s.	
1871	—.126	7
1872	—.078	6
1873	—.109	7
1874	—.009	11
1875	—.030	5
1876	—.163	6

η Draconis.		
Year.	$\Delta\alpha$	No. Obs.
	s.	
1871	—.117	3
1872	—.155	8
1873	—.128	6
1874	—.135	18
1875	—.159	11
1876	—.242	5
1877	—.246	5
1878	—.176	8

Gr. 2377.		
	s.	
1871	—0.75	6
1872	—.110	9
1873	—.130	6
1874	—.050	10
1875	—.083	7
1876	—.119	6

Gr. 2900.		
	s.	
1871	+.340	1
1872	+.113	3
1873	+.117	11
1874	+.230	5

Finally we have the following values for H. C. O. *minus* Pub. XIV. The residuals taken from the Memoir quoted, are also given. It will be remembered that they were derived from the observations of 1871, 1872, 1874, and 1875, by applying the systematic corrections given in Tables I., II., and III.

STAR.	$\Delta\alpha$ from Observations between 1870 and 1878.	$\Delta\alpha$ from Memoir.	Diff.
	s.	s.	s.
Br. 6	+.163	+.170	—.007
η Cassiop.	+.077	+.090	—.013
36 Camelop.	+.067	+.100	—.033
1 H. Draconis	+.204	+.192	+.012
Gr. 2164	—.014	+.087	—.101
θ Draconis	—.080	—.093	+.013
η Draconis	—.164	—.141	—.023
Gr. 2377	—.097	—.093	—.004
Gr. 2900	+.156	+.156	+.000

Aside from the two stars at first noted, it appears, therefore, that with the exception of Gr. 2164 the corrections given in my Memoir are substantiated by the entire series of Harvard College Observatory observations made between 1871 and 1878 inclusive.

Harvard College Observatory,
May 9, 1883.

PROCEEDINGS.

Seven hundred and fifty-third Meeting.

May 30, 1882. — ANNUAL MEETING.

The PRESIDENT in the chair.

The President announced the sudden death of Professor William B. Rogers; also the death of Mr. Edouard Desor, Associate Fellow.

The report of the Treasurer was read and accepted.

On the motion of Professor Pickering, it was

Voted, That the balance of the appropriation for publications made but not expended last year be reappropriated.

The report of the Librarian was read and accepted.

On the motion of Mr. Lyman, it was

Voted, That, when the Academy adjourn, it adjourn to the second Wednesday in June.

Professor Pickering presented a circular relating to a proposed monument to Secchi, the Italian astronomer.

On the motion of Mr. Scudder, it was

Voted, That blank cards be prepared for ordering books for the library.

The annual election resulted in the choice of the following officers: —

JOSEPH LOVERING, *President.*
OLIVER W. HOLMES, *Vice-President.*
JOSIAH P. COOKE, *Corresponding Secretary.*
JOHN TROWBRIDGE, *Recording Secretary.*
THEODORE LYMAN, *Treasurer.*
SAMUEL H. SCUDDER, *Librarian.*

Council.

Wolcott Gibbs,
Edward C. Pickering,
Charles W. Eliot, of Class I.

George L. Goodale,
Henry P. Bowditch,
Asa Gray, of Class II.

Francis J. Child,
Charles G. Loring,
Edward Atkinson, of Class III.

Rumford Committee.

Wolcott Gibbs,
Edward C. Pickering,
John M. Ordway,
John Trowbridge,
Josiah P. Cooke,
Joseph Lovering,
George B. Clark.

Member of Committee of Finance.

Thomas T. Bouvé.

The President appointed the following standing committees: —

Committee of Publication.

Alexander Agassiz,
John Trowbridge,
Francis J. Child.

Committee on the Library.

Edward C. Pickering,
Henry P. Bowditch,
Nathaniel D. C. Hodges.

Auditing Committee.

Henry G. Denny,
Robert W. Hooper.

Seven hundred and fifty-fourth Meeting.

June 14, 1882. — ADJOURNED ANNUAL MEETING.

The PRESIDENT in the chair.

The Treasurer presented a report on appropriations; and it was

Voted, To appropriate for the following year, subject to the approval of a future stated meeting: —

For publishing	$2,000
For library	1,250
For general expenses	2,200

Professor Rogers presented a communication on a method of making a perfect screw.

Seven hundred and fifty-fifth Meeting.

October 11, 1882. — STATED MEETING.

The PRESIDENT in the chair.

The appropriations recommended by the Treasurer at the last meeting were confirmed.

The President read a letter from the Secretary of the Society of Arts inviting the Academy to be present at a meeting in memory of the late Professor William B. Rogers.

The following gentlemen were elected members of the Academy: —

Charles Sedgwick Minot, of Boston, to be a Resident Fellow in Class II., Section 3.

Francis Amasa Walker, of Boston, to be a Resident Fellow in Class III., Section 3.

Bernhard Studer, of Berne, to be a Foreign Honorary Member in Class II., Section 1.

Julius Sachs, of Würzburg, to be a Foreign Honorary Member in Class II., Section 2, in place of the late Joseph Decaisne.

Carl Friedrich Wilhelm Ludwig, of Leipsic, to be a Foreign Honorary Member in Class II., Section 3, in place of the late Theodor Schwann.

The following papers were presented: —

Comparisons of Photometric Observations on the Light of the Stars, made by Sir William Herschel. By Edward C. Pickering.

On the Effect of Change of Temperature on Hall's Phenomena. By Edwin H. Hall. (By invitation.)

Contributions from the Physical Laboratory of Harvard College:

On the Thomson Effect. By John Trowbridge and C. B. Penrose.

Influence of Magnetism on Thermal Conductivity. By John Trowbridge and C. B. Penrose.

Electromotive Force. By John Trowbridge.

Change of Pitch by the Telephone. By John Trowbridge.

Seven hundred and fifty-sixth Meeting.

November 8, 1882. — MONTHLY MEETING.

The PRESIDENT in the chair.

In the absence of the Recording Secretary, Mr. Edmands was appointed Secretary *pro tem.*

The President read a letter from the Directors of the Royal Society of Sciences of Göttingen, announcing the death of their secretary, Friedrich Wöhler; also a letter from Dr. Charles S. Minot, acknowledging his election as Fellow of the Academy.

The following paper was presented by title: —

The Tortugas and Florida Reef. By Alexander Agassiz.

Professor Dolbear made some remarks on the maximum temperature of the sun. He also spoke of an attempt to determine the relative amounts of electricity transmitted by different parts of the cross section of a conductor. Remarks on this subject were made by Messrs. Pickering and Edmands.

Seven hundred and fifty-seventh Meeting.

December 13, 1882. — Monthly Meeting.

The President in the chair.

The President announced the death of Professor Bischoff, Foreign Honorary Member.

Letters were read from Messrs. Studer and Ludwig, acknowledging their election as Foreign Honorary Members.

The following papers were presented: —

On the Determination of the Diameters of Planets by the Method of Inclined Lines. By William A. Rogers.

Preliminary Notice of the Action of Phosphorous Trichloride on Anilin. By C. Loring Jackson and A. E. Menke.

Professor Pickering gave an account of the observations of the recent transit of Venus made at the Harvard College Observatory.

Mr. Searle made some remarks on the brightness of Venus at the time of transit, and on the zodiacal light.

Seven hundred and fifty-eighth Meeting.

January 10, 1883. — Stated Meeting.

The Vice-President in the chair.

On the motion of the Corresponding Secretary, it was

Voted, That, when the Academy adjourn, it adjourn to the second Wednesday in February.

The following papers were presented by title: —

On the Products of the Dry Distillation of Wood at Low Temperatures. By Charles F. Mabery.

On certain Substituted Acrylic and Propionic Acids. P Charles F. Mabery and Franklin C. Robinson.

On the Decomposition of Chlortribrompropionic Charles F. Mabery.

Seven hundred and fifty-ninth Meeting.

February 14, 1883. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The following gentlemen were elected members of the Academy: —

Samuel Pierpont Langley, of Allegheny, to be an Associate Fellow in Class I., Section 2.

Seth Carlo Chandler, Jr., of Cambridge, to be a Resident Fellow in Class I., Section 2.

Edwin Herbert Hall, of Cambridge, to be a Resident Fellow in Class I., Section 3.

William White Jacques, of Newburyport, to be a Resident Fellow in Class I., Section 3.

Louis Pasteur, of Paris, to be a Foreign Honorary Member in Class II., Section 3, in place of the late Charles Robert Darwin.

Matthew Arnold, of Gorham, England, to be a Foreign Honorary Member in Class III., Section 4, in place of the late Arthur Penrhyn Stanley.

The following papers were presented: —

Quantitative Researches in Photography. By William H. Pickering. (By invitation.)

Photography as a Means of Determining the Light and Color of the Stars. By Edward C. Pickering and William H. Pickering.

On the Historical Hydrography of the West Coast of North America. By Justin Winsor.

Seven hundred and sixtieth Meeting.

March 14, 1883. — STATED MEETING.

PRESIDENT in the chair.

h of Mr. Nathaniel Thayer was announced.

ng gentlemen were elected members of the

Seven hundred and fifty-seventh Meeting.

December 13, 1882. — MONTHLY MEETING.

The PRESIDENT in the chair.

The President announced the death of Professor Bischoff, Foreign Honorary Member.

Letters were read from Messrs. Studer and Ludwig, acknowledging their election as Foreign Honorary Members.

The following papers were presented: —

On the Determination of the Diameters of Planets by the Method of Inclined Lines. By William A. Rogers.

Preliminary Notice of the Action of Phosphorous Trichloride on Anilin. By C. Loring Jackson and A. E. Menke.

Professor Pickering gave an account of the observations of the recent transit of Venus made at the Harvard College Observatory.

Mr. Searle made some remarks on the brightness of Venus at the time of transit, and on the zodiacal light.

Seven hundred and fifty-eighth Meeting.

January 10, 1883. — STATED MEETING.

The VICE-PRESIDENT in the chair.

On the motion of the Corresponding Secretary, it was

Voted, That, when the Academy adjourn, it adjourn to the second Wednesday in February.

The following papers were presented by title: —

On the Products of the Dry Distillation of Wood at Low Temperatures. By Charles F. Mabery.

On certain Substituted Acrylic and Propionic Acids. By Charles F. Mabery and Franklin C. Robinson.

On the Decomposition of Chlortribrompropionic Acid. By Charles F. Mabery.

Seven hundred and fifty-ninth Meeting.

February 14, 1883. — ADJOURNED STATED MEETING.

The PRESIDENT in the chair.

The following gentlemen were elected members of the Academy: —

Samuel Pierpont Langley, of Allegheny, to be an Associate Fellow in Class I., Section 2.

Seth Carlo Chandler, Jr., of Cambridge, to be a Resident Fellow in Class I., Section 2.

Edwin Herbert Hall, of Cambridge, to be a Resident Fellow in Class I., Section 3.

William White Jacques, of Newburyport, to be a Resident Fellow in Class I., Section 3.

Louis Pasteur, of Paris, to be a Foreign Honorary Member in Class II., Section 3, in place of the late Charles Robert Darwin.

Matthew Arnold, of Gorham, England, to be a Foreign Honorary Member in Class III., Section 4, in place of the late Arthur Penrhyn Stanley.

The following papers were presented: —

Quantitative Researches in Photography. By William H. Pickering. (By invitation.)

Photography as a Means of Determining the Light and Color of the Stars. By Edward C. Pickering and William H. Pickering.

On the Historical Hydrography of the West Coast of North America. By Justin Winsor.

Seven hundred and sixtieth Meeting.

March 14, 1883. — STATED MEETING.

The PRESIDENT in the chair.

The death of Mr. Nathaniel Thayer was announced.

The following gentlemen were elected members of the Academy: —

Silas Whitcomb Holman, of Boston, to be a Resident Fellow in Class I., Section 3.

Leonard Parker Kinnicutt, of Cambridge, to be a Resident Fellow in Class I., Section 3.

Charles Frederic Mabery, of Cambridge, to be a Resident Fellow in Class I., Section 3.

William Henry Pickering, of Boston, to be a Resident Fellow in Class I., Section 3.

Walter Faxon, of Cambridge, to be a Resident Fellow in Class II., Section 3.

Johann Friedrich Julius Schmidt, of Athens, to be a Foreign Honorary Member in Class I., Section 2, in place of the late Emile Plantamour.

Thomas Henry Huxley, of London, to be a Foreign Honorary Member in Class II., Section 3, in place of the late Theodor Ludwig Wilhelm Bischoff.

The following papers were presented: —

On a Method of Observing the Occultations of Jupiter's Satellites. By Edward C. Pickering.

On an Electrical Method of Communicating Intelligence from a Vessel at Sea to a Station on Shore. By Amos E. Dolbear.

The following papers by Professor William A. Rogers were presented by title: —

Determination of the Absolute Coefficient of Expansion of Bars of Copper, Bronze, and Brass.

A New Method of Determining, from Observations of the Pole Star, the Equator Point Correction of a Meridian Circle at any Instant of Time.

A New Method of Determining the Flexure of the Graduated Circle of a Meridian Instrument.

Seven hundred and sixty-first Meeting.

April 11, 1883. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read an invitation to the American Academy from the Royal Society of Canada to attend their second meeting at Ottawa.

An invitation to attend the semi-centennial meeting of the Oberhessische Gesellschaft für Natur- und Heilkunde at Giessen was also read. On the motion of the Corresponding Secretary, it was

Voted, To accept these invitations.

Dr. Otto W. Struve, of Pulkowa, read a paper on Aberration.

Professor Lovering showed the bearing of the refined observations of the Pulkowa Observatory upon the question of the influence of the movement of the ether upon aberration and refraction.

The following papers were presented: —

Results of the Comparisons of Three Independent Copies of the Imperial Yard and of Four Independent Copies of the Metre of the Archives. By William A. Rogers.

On the Earliest Observation of a Variable Star. By Seth C. Chandler, Jr.

On the Photographs of Stellar Spectra made by the late Dr. Henry Draper. By Edward C. Pickering.

The following papers were presented by title: —

On Substituted Pyromucic Acids. By Henry B. Hill.

On certain Parabrombenzyl Compounds. By C. Loring Jackson and G. T. Hartshorn.

Notes on the Cryptogamic Flora of the White Mountains. By William G. Farlow.

Seven hundred and sixty-second Meeting.

May 9, 1883. — MONTHLY MEETING.

The PRESIDENT in the chair.

The Corresponding Secretary read letters from the Congrès International des Américanistes, at Copenhagen; from Señor Anguiano, Director of the National Observatory of Mexico, at Tacubaya; from Messrs. Huxley and Schmidt, acknowledging election as Foreign Honorary Members.

On the motion of the Corresponding Secretary, it was

Voted, To appoint Professor Alpheus Hyatt a delegate to represent the American Academy at the meeting of the Royal Society of Canada.

The President announced informally that, at the annual meeting of the Academy, the Rumford Committee would recommend that the Rumford Medal be awarded Professor Henry A. Rowland for his researches on light and heat.

The following papers were presented: —

On the Collection of Meteorites at Harvard College. By Josiah P. Cooke.

Photographs of the Infra Red Portion of the Spectrum. By William H. Pickering.

The following papers were presented by title: —

Contributions to American Botany. 1. Characters of and Notes upon North American and Mexican Compositæ. 2. Characters of various other North American Gamopetalæ. By Asa Gray.

A Simple Method of Correcting the Weight of a Body for the Buoyancy of the Atmosphere when the Volume is unknown. By Josiah Parsons Cooke.

On the Vapor Density of the Chloride, the Bromide, and the Iodide of Antimony. By C. P. Worcester.

Notes on some Species in the Third and Eleventh Centuries of Ellis's North American Fungi. By William G. Farlow.

Contributions to American Botany. By Sereno Watson.

On the Heat produced in Iron and Steel by Reversals of Magnetization. By John Trowbridge and Walter N. Hill.

On the Heat produced in Iron and Steel by Reversals of Magnetization. By John Trowbridge and Charles Bingham Penrose.

Influence of Magnetism upon Thermal Conductivity. By John Trowbridge and Charles Bingham Penrose.

Papers on Thermo-Electricity. No. 1. By John Trowbridge and Charles Bingham Penrose.

The Electromotive Force of Alloys. By John Trowbridge and E. K. Stevens.

The Potential of a Shell bounded by Confocal Ellipsoidal Surfaces. By Frank Nelson Cole.

Researches on the Complex Inorganic Acids. By Wolcott Gibbs.

The Volumetric Determination of Combined Nitrous Acid. By Leonard P. Kinnicutt and John U. Nef.

The β Phenyltribrompropionic Acid. By Leonard P. Kinnicutt.

On the Crystalline Form of Chlordibromacrylic Acid. By Oliver W. Huntington.

On the Reduction of Different Star Catalogues to a Common System. By William A. Rogers.

On a Method of Determining the Index Error of a Meridian Circle at any Instant impending upon the Observed Polar Distance of Polaris. By William A. Rogers.

Studies in Metrology. First Part. By William A. Rogers.

On a New Method of Preparing Borneol from Camphor. By C. Loring Jackson and A. E. Menke.

REPORT OF THE COUNCIL.

MAY 29, 1883.

During the past year the Academy has lost by death twelve members; — viz. four Resident Fellows: Augustus A. Hayes, William B. Rogers, Chandler Robbins, and Nathaniel Thayer; four Associate Fellows: Charles Avery, of Clinton, N. Y., Henry Draper, of New York City, George P. Marsh, of Rome, and Isaac Ray, of Philadelphia; and four Foreign Honorary Members: T. L. W. Bischoff, of Munich, Joseph Liouville, of Paris, Emile Plantamour, of Geneva, and Friedrich Wöhler, of Göttingen.

JOHN BACON.*

JOHN BACON was born in Boston, September 8, 1817. His father, John Bacon senior, came from Haverhill, England, during the year 1812, and established himself in the drug business, on the site of the present Court House, on Court Street, Boston. He soon became well known as an active merchant, and during his successful life was highly respected and beloved. He was a leader in many political, financial, and charitable movements, and was a member of the Old North Church and for many years one of its wardens.

Soon after his arrival in Boston, John Bacon senior married Ann Hart, daughter of Edmund Hart, remembered in Boston as the builder of the frigate Constitution. The children of this marriage were John, the subject of this notice, and Anna, who in after life became the second wife of Rollin H. Neale, a distinguished Baptist clergyman.

The son John in his boyhood was noted for his quiet and gentlemanly deportment, and early manifested a strong taste for mechanics.

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* This notice should have been included in the Report of last year, but was not ready in time.

He was educated at the Boston Latin School, and at Harvard College, where he graduated with the Class of 1837, being at that time not quite twenty years of age. Both at school and at college young Bacon was an excellent scholar, and is remembered with respect and affection by those of his classmates who enjoyed his intimacy. He had a warm and generous heart, a sympathetic smile, with genial manners, and a quiet vein of humor which endeared him to those who could draw him out of himself; but one of his classmates writes, "He was one of the least demonstrative persons I ever knew."

After his graduation, Bacon entered the Medical School in Boston connected with Harvard University, and received in regular course the degree of M. D., although he never practised the medical profession. Soon after, he made an extended tour in Europe when such a privilege was more rare than at the present time, and this journey gave him the opportunity to pursue effectively the study of chemistry, for which he had acquired a strong taste, and which he continued with great assiduity after his return home.

The bias of his professional associations naturally gave direction to Dr. Bacon's chemical studies, and he soon became the leading authority in this community on all questions of physiological chemistry. He very early applied the microscope to the examination of urinary deposits, and his skill in the preparation of objects for study was remarkably great, and it is to be hoped that the very large and unique collection of these objects which he made has not been lost to science. His private laboratory was a model of order and neatness; his reagents were preserved in the greatest possible purity, and his instruments kept in the most serviceable condition.

In 1847, Dr. Bacon, then at the age of twenty-nine, was elected a Fellow of this Academy; but, so far as the writer can discover, he made but one communication to the Academy which was published in its Proceedings. Most of his papers, generally very brief, were published either in the Boston Journal of Natural History, or in medical journals. As complete a list of these papers as the zeal of a friend can now secure is given below. Dr. Bacon's modest and retiring disposition kept him from being much before the world; but when he was called on for an opinion on matters relating to his peculiar department of study, he would give it with decision, and show the result of thorough knowledge, careful observation, and large experience.

In 1851, Dr. Bacon was appointed Chemist and Microscopist to the Massachusetts General Hospital, a position which gave him great facilities for pursuing his special studies, and which he held until 1863.

In 1857, when, in consequence of increasing work in the Undergraduate Course, the Erving Professor in Harvard College was relieved of all duties at the Medical School, Dr. Bacon was appointed Professor of Chemistry in that School and remained a member of the Medical Faculty of Harvard University until 1871. As a lecturer, he commanded the respect and attention of the students, and in the laboratory he won their confidence and esteem. He was a successful experimenter, and combined great clearness of thought with felicity of illustration.

Dr. Bacon was a man of slight build, and seems never to have enjoyed robust health. He resigned first his position in the Hospital and then his professorship, on account of failing strength; and a fever which he passed through soon afterwards still further impaired his energies. A man of quiet habits and reticent manners, he made few new friends, but was beloved heartily by those who knew his virtues and the warmth of his affections. After the death of his sister, Mrs. Neale, and later of her husband, leaving him the last of the household, his ill health, aggravated by depression of spirits, led him to shrink more than ever within himself. He saw only a few old friends, and sought companionship chiefly in his books. His closing years were clouded also by financial troubles, which conspired to aggravate his morbid condition. His last strong love was for his Alma Mater. In one of his latest notes, written by him but a few hours before his death, were these words: "Save out of the wreck all you can for my beloved College." It had been the great desire of Dr. Bacon's life to found at the University a Professorship of Chemistry, to be known as the Bacon Professorship, and to this the note referred. The word "wreck" plainly shows the great weakness of his condition just before his decease. He died, November 28, 1881, at his residence on Somerset Street, Boston, aged sixty-four. There was no wreck. Dr. Bacon left the greater part at least of the considerable estate he had inherited from his father; but unfortunately he had not so ordered his affairs as to make his last wish effective.

Papers by John Bacon, M. D.

1. Polythalamia in Sand from the Sahara Desert. Bost. Journ. Nat. Hist., V., p. 402; also Proc. Bost. Nat. Hist. Soc., II., 1846, p. 164.
2. Microscopic Examination of Gun-Cotton. Proc. Bost. Soc. Nat. Hist., II., 1847, p. 195; Amer. Journ. Sci., 2 ser., IV., 1847, p. 445.
3. Observations on the Dumb-bell Urinary Deposit. Amer. Journ. Med. Sci., n. s., XXI., 1851, p. 297.
4. Urinary Deposit of Epithelial Nuclei. Amer. Journ. Med. Sci., n. s., XXIV., 1852, p. 378.

5. Crystals of Hæmatoidin in the Bloody Fluid from a Tumor. Amer. Journ. Med. Sci., n. s., XXIV., 1852, p. 380.
6. Mercurial Poisoning. Amer. Journ. Med. Sci., n. s., XXVI., 1853, p. 91.
7. Calculi passed per Urethram. Amer. Journ. Med. Sci., n. s., XXVI., 1853, p. 363.
8. Factitious Bezoar. Amer. Journ. Med. Sci., n. s., XXVII., 1854, p. 346.
9. Proportion of Fat in a Fatty Liver. Amer. Journ. Med. Sci., n. s., XXVII., 1854, p. 355.
10. Observations on the Oil contained in the Crustaceans found in the Cochituate Water. Proc. Amer. Acad., III., 1855, p. 178; Amer. Journ. Sci., 2 ser., XIX., 1855, p. 261.
11. With A. A. Hayes. Researches upon Cochituate Water, and upon the Oily Matter and Crustacea contained therein. Proc. Bost. Soc. Nat. Hist., V., 1855, p. 144.
12. Fossil Foraminifera from South Carolina, and Polycistina from Barbadoes, Proc. Bost. Soc. Nat. Hist., VI., 1857, p. 246.
13. Microscopic Forms of Oxalate of Lime. Proc. Bost. Soc. Nat. Hist., VI., 1857, p. 263.
14. Frequency of the Crystalline Urinary Deposits at the Massachusetts General Hospital. Bost. Med. and Surg. Journ., LVIII., 1858, p. 11.
15. Introductory Address [delivered November 3d, 1858, to the Medical Class of Harvard University]. Bost. Med. and Surg. Journ., LIX., 1858, p. 289.
16. Elimination of Lead from the System. Bost. Med. and Surg. Journ., LX., 1859, p. 429.
17. On Cocoa-nut Pearl. Proc. Bost. Soc. Nat. Hist., VII., 1860, p. 290.
18. Calculus, partly Siliceous, from the Kidney of a Sheep. Bost. Med. and Surg. Journ., LXIV., 1861, p. 211.
19. Note concerning the Cocoa-nut Pearl. Proc. Bost. Soc. Nat. Hist., VIII., 1861, p. 173.
20. Siliceous Urinary Calculi. Bost. Med. and Surg. Journ., LXIV., 1861, p. 417.
21. Chemical Analysis of Three Calculi from the Kidney of an Ox. Bost. Med. and Surg. Journ., LXIV., 1861, p. 473.
22. Siliceous Urinary Calculi. Proc. Bost. Soc. Nat. Hist., VIII., 1861, p. 206.
23. Siliceous Calculi from the Kidney of an Ox. Bost. Med. and Surg. Journ., LXV., 1861, p. 132.
24. Arsenical Paper Hangings. Bost. Med. and Surg. Journ., LXIX., 1864, p. 489.

AUGUSTUS ALLEN HAYES.

Augustus Allen Hayes was born at Windsor, Vermont, February 28, 1806. He graduated at the Military Academy at Norwich in 1823, and began the study of chemistry as a profession under Doctor James F. Dana, then Professor of Chemistry and Mineralogy at Dartmouth College. In 1825, a laborious research undertaken by him for the purpose of accurately determining the proximate composition of various American medicinal plants was rewarded, among other results, by the discovery of the organic alkaloid sanguinaria, a compound remarkable for the brilliant color of its salts, although itself nearly colorless. In 1827 he investigated the compounds of chromium, and his paper on this subject was highly praised by Berzelius. Removing to Boston in 1828, he resided in that city or its vicinity until his death. He devoted his time to chemical investigations, and also filled successively the posts of director of an extensive manufactory of colors and chemical products at Roxbury, of consulting chemist or director of some of the most important manufacturing establishments in New England, and of State Assayer of Massachusetts. In 1837 he conducted an elaborate investigation upon the economical generation of steam and the relative value of fuels, which, in 1838, led to a novel arrangement of steam-boilers, afterwards generally adopted. Some of the results of this investigation are embodied in the "Report to the Navy Department of the United States on American Coals applicable to Steam Navigation, and to other Purposes," by the late Walter R. Johnson. To Doctor Hayes belongs also the credit of the important application of the oxides of iron in refining pig-iron in the puddling-furnace so as to produce without loss a pure malleable iron. Still earlier, the refining of copper was, under his direction, rendered a much shorter and more certain operation by the introduction of the scales of oxide of copper produced in refining. His researches on the difference in the chemical constitution and action of sea waters, on and below the surface, on soundings, and at the entrance of rivers, form part of an investigation undertaken under a commission from the United States Navy Department to examine and report on the subject of copper and copper sheathing as applied in the construction of national vessels, and his report embodies a vast amount of scientific and commercial information. In 1859–60, while considering the question of water supply for the city of Charlestown, he found, as his earlier analysis indicated, that the deep water of Mystic Pond was far less pure than the surface water. The question of diffusion under a flowing surface came up for study, with the responsibility of accepting or rejecting the source of supply. He had proved that a copper strip or wire, passing vertically through two masses of water of slightly unlike composition, would become polarized and exhibit electrolytic action. This mode of testing the exact limits of the impure water was applied under his direction, and it was shown that a compound affording sulphur, when decomposed, could be detected by its action on the strip forming a black sulphide, and the limits of the existence of this compound were read on the surface of the strip of copper, or silvered copper. Numerous observations on this and other bodies of water have proved the high practical value of the application, and demonstrated the presence of a stream of naturally pure water, nearly twenty feet deep, flowing without contamination over impure water. After the outbreak of the civil war, Doctor Hayes called public attention to the uncertainty of the foreign supply of saltpetre, and the necessity of domestic production. His efforts resulted in the manufacture of the supply for the navy from caustic potash and nitrate of soda by a novel process, the product being of great purity.

Doctor Hayes visited Europe in 1867, and after his return, at the close of the following year, was attacked by a serious illness. Recovering from the first shock, he lived nearly thirteen years, enduring continuous suffering with great patience and tranquillity. He died at his home in Longwood, June 21, 1882, at the age of seventy-six years. His wife, the daughter of the Rev. Samuel Dana of Marblehead, who had devoted herself wholly to caring for him during his long sickness, had died previously, in 1879.

The honorary degree of M. D. was conferred on Doctor Hayes in 1846 by Dartmouth College, to which institution he afterwards presented his scientific library. He was elected Fellow of this Academy, August 8, 1838, and his last scientific communication, that on the wide distribution of vanadium, was made to our body. He had the rare faculty of interesting practical men in scientific subjects, and his familiar talks at the meetings of the Thursday Evening Club were highly esteemed in Boston. His chief occupation was that of a consulting chemist, and he was for many years the chief authority in this vicinity on all the great commercial questions involving chemical principles. His opinions were highly valued, and the many industrial interests wisely fostered under his direction gave him an ample competency. He was a warm and generous friend, quick and ardent in his sympathies, full of kindness and good works. During his long illness, when, after such an active life, he was confined either to his bed or to an invalid's chair, he showed a fortitude, a resignation, and a cheerfulness which made a visit to his home an attractive pilgrimage, and these qualities, which won at the time the admiration of his friends, may be here recorded for a memorial of the nobility of his character.

Papers by Augustus Allen Hayes, M. D.

1. Localities of Minerals in Vermont. Sill Journ., XIII, 1828, pp. 195, 196.
2. On the Combinations of Chromium. Sill. Journ., XIV., 1828, pp. 136–144.
3. On a Portable Hygrometer. Sill. Journ., XVII., 1830, pp. 351, 352.

4. On the Dew-Point. Sill. Journ., XVIII., 1830, pp. 63–65.
5. Hydrobromic Acid and Potash in the Saratoga Springs. Sill. Journ., XVIII., 1830, pp. 142, 143.
6. Production of Hydrocyanic (Prussic) Acid under uncommon Circumstances. Roy. Inst. Journ., I., 1831, p. 169.
7. On a Singular Instance of Crystallization. Sill. Journ., XX., 1831, pp. 128–130.
8. Notice of Cobalt, Nickel, &c., of the Chatham Mine, Connecticut. Sill. Journ., XXI., 1832, pp. 195, 196.
9. On two new Acid Compounds of Chlorine, Carbon, and Hydrogen. Sill. Journ., XXII., 1832, pp. 141–143.
10. Details of a Chemical Analysis of Danaite, a new Ore of Iron and Cobalt. Sill. Journ., XXIV., 1833, pp. 386–388.
11. On the Action of Metallic Tin on Solutions of Muriate of Tin. Sill. Journ., XXXVIII., 1840, pp. 408–410; Sturgeon, Ann. Electr., V., 1840, pp. 302, 303; Bibl. Univ., XXX., 1840, pp. 411–413.
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CHANDLER ROBBINS.

Chandler Robbins was born at Lynn, Massachusetts, February 14, 1810. He graduated at Harvard University in 1829, having maintained a high rank in a class of unusual ability and promise. He spent a year as a teacher in the Boston Latin School, and then entered the Cambridge Divinity School. In 1833 he became pastor of the Second Church in Boston, succeeding in that office Ralph Waldo Emerson. He resigned his pastorate in 1874, and died at Weston, Massachusetts, September 11, 1882. In his profession he was successful as a preacher; eminently assiduous, faithful, and beloved, as a pastor. His style was chaste and pure, his delivery graceful. He possessed in full measure the endowments that belong to the Christian gentleman, scholar, and minister. He had a by no means shallow vein of poetical sentiment, and contributed to the hymnology of the Church several favorite Christian lyrics. His principal extra-professional labors were in the department of history, in which he published many discourses, lectures, and articles, besides serving for many years in various offices in the Massachusetts Historical Society, and aiding in the preparation and editorship of several volumes of its collections. In 1855 he received the degree of Doctor of Divinity from Harvard University. For the latter years of his life a gradual failure of eyesight, terminating in total blindness, disabled him for active duty, and at the same time brought into conspicuous exercise those passive virtues which grow only from profound religious faith, trust, and experience.

WILLIAM BARTON ROGERS.

William Barton Rogers was born at Philadelphia, on the 7th of December, 1804. His father, Patrick Kerr Rogers, was a native of Newton Stewart, in the north of Ireland; but while a student at Trinity College, Dublin, becoming an object of suspicion on account of his sympathy with the unfortunate Robert Emmet, he emigrated to this country, and finished his education in the University of Pennsylvania, at Philadelphia, where he received the degree of Doctor of Medicine.

Here he married Hannah Blythe, a Scotch lady, — who was at the time living with her aunt, Mrs. Ramsay, — and settled himself in his profession in a house on Ninth Street, opposite to the University; and in this house William B. Rogers was born. He was the second of four sons, — James, William, Henry, and Robert, — all of whom became distinguished as men of science.

Patrick Kerr Rogers, finding that his prospects of medical practice in Philadelphia had been lessened in consequence of a protracted absence in Ireland, made necessary by the death of his father, removed to Baltimore; but soon afterwards accepted the Professorship of Chemistry and Physics in William and Mary College, Virginia, made vacant by the resignation of the late Robert Hare; and it is a fact worthy of notice, that, while he succeeded Dr. Hare at William and Mary College, his oldest son, James, succeeded Dr. Hare at the University of Pennsylvania. At William and Mary College the four brothers Rogers were educated; and on the death of the father, at Ellicott Mills, in 1828, William B. Rogers succeeded to the professorship thus made vacant.

He had already earned a reputation as a teacher by a course of lectures before the Maryland Institute in Baltimore during the previous year, and after his appointment at once entered on his career as a scientific investigator. At this period he published a paper on Dew, and, in connection with his brother Henry, another paper on the Voltaic Battery, — both subjects directly connected with his professorship. But his attention was early directed to questions of chemical geology; and he wrote, while at William and Mary College, a series of articles for the Farmer's Register on the Green Lands and Marls of Eastern Virginia, and their value as fertilizers. Next we find the young Professor going before the legislature of Virginia, and, while modestly presenting his own discoveries, making them the occasion for urging upon that body the importance of a systematic geological survey for developing the resources of the State. So great was the scientific reputation that Professor Rogers early acquired by such services, that in 1835 he was called to fill the important Professorship of Natural Philosophy and Geology in the University of Virginia; and during the same year he was appointed State Geologist of Virginia, and began those important investigations which will always associate his name with American geology.

Professor Rogers remained at the head of the Geological Survey of Virginia until it was discontinued, in 1842, and published a series of very valuable annual reports. As was anticipated, the survey led to a large accumulation of material, and to numerous discoveries of great local importance. As this was one of the earliest geological surveys undertaken in the United States, its directors had in great measure to devise the methods and lay out the plans of investigation which have since become general. This is not the place, however, for such details; but there are four or five general results of Professor Rogers's geological work at this period which have exerted a permanent influence on geological science, and which should therefore be briefly noticed. Some of these results were first published in the American Journal of Science; others were originally presented to the Association of American Geologists and Naturalists, and published in its "Transactions." Professor Rogers took a great interest in the organization of this association in 1840, presided over its meeting in 1845, and again, two years later, when it was expanded into the American Association for the Advancement of Science.

In connection with his brother Robert, Professor William B. Rogers was the first to investigate the solvent action of water — especially when charged with carbonic acid — on various minerals and rocks; and by showing the extent of this action in nature, and its influence in the formation of mineral deposits of various kinds, he was one of the first to observe and interpret the important class of facts which are the basis of chemical geology.

Another important result of Professor Rogers's geological work was to show that the condition of any coal-bed stands in a close genetic relation to the amount of disturbance to which the enclosing strata have been submitted, the coal becoming harder and containing less volatile matter as the evidence of disturbance increases. This generalization, which seems to us now almost self-evident, — understanding, as we do, more of the history of the formation of coal, — was with Professor Rogers an induction from a great mass of observed facts.

By far, however, the most memorable contribution of Professor Rogers to geology was that made in connection with Henry D. Rogers, in a paper entitled "The Laws of Structure of the more Disturbed Zones of the Earth's Crust," presented by the two brothers at the meeting of the Association of American Geologists and Naturalists, held at Boston in 1842. This paper was the first presentation of what may be called in brief *the Wave Theory of Mountain Chains*. This theory was deduced by the brothers Rogers from an extended study of the Appalachian chain in Pennsylvania and Virginia, and was supported by numerous geological sections and by a great mass of facts. The hypothesis which they offered as an explanation of the origin of the great mountain waves may not be generally received; but the general fact that the structure of mountain chains is alike in all the essential features which the brothers Rogers first pointed out, has been confirmed by the observations of Murchison in the Ural, of Darwin in the Andes, and of the Swiss geologists in the Alps. "In the Appalachians the wave structure is very simple, and the same is true in all corrugated districts where the crust movements have been simple, and have acted in one direction only. But where the elevating forces have acted in different directions at different times, causing interference of waves like a chopped sea, as in the Swiss Alps and the mountains of Wales or Cumberland, the undulations are disguised, and are with extreme difficulty made out." The wave theory of mountain chains was the first important contribution to dynamical and structural geology which had been brought forward in this country. It excited at the time great interest, as well from the novelty of the views as from the eloquence with which they were set forth; and to-day it is still regarded as one of the most important advances in orographic geology.

A marked feature of mountain regions is that rupturing of the strata called faults; and another of the striking geological generalizations of the brothers Rogers is what may be called the law of the distribution of faults. They showed that faults do not occur on gentle waves, but in the most compressed flexures of the mountain chains, which in the act of moving have snapped or given way at the summit where the bend is sharpest, the less inclined side being shoved up on the plane of the fault, this plane being generally parallel to, if it does not coincide with, the axis plane; and, further, that "the direction of these faults generally follows the run of the line of elevation of the mountains, the length and vertical displacement depending on the strength of the disturbing force."

The last of the general geological results to which we referred above was published under the name of William B. Rogers only. It was based on the observed positions of more than fifty thermal springs in the Appalachian belt, occurring in an area of about fifteen thousand square miles, which were shown to issue from anticlinal axes and faults, or from points very near such lines; and in connection with these springs it was further shown that there was a great preponderance of nitrogen in the gases which the waters held in solution.

It must be remembered that, during the time when this geological work was accomplished, Professor Rogers was an active teacher in the University of Virginia, giving through a large part of the year almost daily lectures either on physics or geology. Those who met him in his after life in various relations in Boston, and were often charmed by his wonderful power of scientific exposition, can readily understand the effect he must have produced, when in the prime of manhood, upon the enthusiastic youths who were brought under his influence. His lecture-room was always thronged. As one of his former students writes, "All the aisles would be filled, and even the windows crowded from the outside. In one instance I remember the crowd had assembled long before the hour named for the lecture, and so filled the hall that the Professor could only gain admittance through a side entrance leading from the rear of the hall through the apparatus-room. These facts show how he was regarded by the students of the University of Virginia. His manner of presenting the commonest subject in science — clothing his thoughts, as he always did, with a marvellous fluency and clearness of expression and beauty of diction — caused the warmest admiration, and often aroused the excitable nature of Southern youths to the exhibition of enthusiastic demonstrations of approbation. Throughout Virginia, and indeed the entire South, his former students are scattered, who even now regard it as one of the highest privileges of their lives to have attended his lectures."

Such was the impression which Professor Rogers left at the University of Virginia, that, when he returned thirty-five years later to aid in the celebration of the semi-centennial, he was met with a perfect ovation. Although the memories of the civil war, which had intervened, and Professor Rogers's known sympathies with the Northern cause, might well have damped enthusiasm, yet the presence of the highly honored teacher was sufficient to rekindle the former admiration; and, in the language of a contemporary Virginia newspaper, "the old students beheld before them the same William B. Rogers who thirty-five years before had held them spellbound in his class of natural philosophy; and as the great orator warmed up, these men forgot their age; they were again young, and showed their enthusiasm as wildly as when, in days of yore, enraptured by his eloquence, they made the lecture-room of the University ring with their applause."

Besides his geological papers, Professor Rogers published, while at the University of Virginia, a number of important chemical contributions, relating chiefly to new and improved methods in chemical analysis and research. These papers were published in connection with his youngest brother, Robert E. Rogers, now become his colleague as Professor of Chemistry and Materia Medica in the University; and such were the singularly intimate relations between the brothers that it is often impossible to dissociate their scientific work. Among these were papers "On a New Process for obtaining Pure Chlorine"; "A New Process for obtaining Formic Acid, Aldehyde, etc."; "On the Oxidation of the Diamond in the Liquid Way"; "On New Instruments and Processes for the Analysis of the Carbonates"; "On the Absorption of Carbonic Acid by Liquids"; besides the extended investigation "On the Decomposition of Minerals and Rocks by Carbonated and Meteoric Waters," to which we have referred above. There was also at this time a large amount of chemical work constantly on hand in connection with the Geological Survey, such as analyses of mineral waters, ores, and the like. Moreover, while at the University of Virginia, Professor Rogers published a short treatise on "The Strength of Materials," and a volume on "The Elements of Mechanics," — books which, though long out of print, were very useful text-books in their day, and are marked by the clearness of style and felicity of explanation for which the author was so distinguished.

The year 1853 formed a turning-point in Professor Rogers's life. Four years previously he had married Miss Emma Savage, daughter of Hon. James Savage of Boston, the well-known author of the New England Genealogical Dictionary, and President of the Massachusetts Historical Society. This connection proved to be the crowning blessing of his life. Mrs. Rogers, by her energy, her intelligence, her cheerful equanimity, her unfailing sympathy, became the promoter of his labors, the ornament and solace of his middle life, and the devoted companion and support of his declining years. Immediately after his marriage, June 20, 1849, he visited Europe with his wife, and was present at the meeting of the British Association for the Advancement of Science, held that year at Birmingham, where he was received with great warmth, and made a most marked impression. Returning home in the autumn, Professor Rogers resumed his work at the University beautiful optical proof of the discontinuity of the singing hydrogen flame.

In 1861 Professor Rogers accepted from Governor Andrew the office of Inspector of Gas and Gas-Meters for the State of Massachusetts, and organized a system of inspection in which he aimed to apply the latest scientific knowledge to this work; and in a visit he again made to Europe in 1864 he presented, at the meeting of the British Association at Bath, a paper entitled "An Account of Apparatus and Processes for Chemical and Photometrical Testing of Illuminating Gas."

During this period he gave several courses of lectures before the Lowell Institute of Boston, which were listened to with the greatest enthusiasm, and served very greatly to extend Professor Rogers's reputation in this community. Night after night, crowded audiences, consisting chiefly of teachers and working-people, were spellbound by his wonderful power of exposition and illustration. There was a great deal more in Professor Rogers's presentation of a subject than felicity of expression, beauty of language, choice of epithets, or significance of gesture. He had a power of marshalling facts, and bringing them all to bear on the point he desired to illustrate, which rendered the relations of his subject as clear as day. In listening to this powerful oratory one only felt that it might have had, if not a more useful, still a more ambitious aim; for less power has moved senates and determined the destinies of empires.

The interest in Professor Rogers's lectures was not excited solely, however, by the charm of his eloquence; for, although such was the felicity of his presentations, and such the vividness of his descriptions, that he could often dispense with the material aids so essential to most teachers, yet when the means of illustration were at his command he showed his power quite as much in the adaptation of experiments as in the choice of language. He well knew that experiments, to be effective, must be simple and to the point; and he also knew how to impress his audience with the beauty of the phenomena and with the grandeur of the powers of nature. He always seemed to enjoy any elegant or striking illustration of a physical principle even more than his auditors, and it was delightful to see the enthusiasm which he felt over the simplest phenomena of science when presented in a novel way.

We come now to the crowning and greatest work of Professor Rogers's life, the founding of the Massachusetts Institute of Technology, — an achievement so important in its results, so far-reaching of Virginia; but the new family relations which had been established led in 1853 to the transfer of his residence to Boston, where a quite different, but even a more important, sphere of usefulness surrounded him. His wide scientific reputation, as well as his family connection, assured him a warm welcome in the most cultivated circles of Boston society, where his strength of character, his power of imparting knowledge, and his genial manners, soon commanded universal respect and admiration. He at once took an active part in the various scientific interests of the city. From 1845 he had been a Fellow of this Academy; and after taking up his residence among us he was a frequent attendant on our meetings, often took part in our proceedings, became a member of our Council, and from 1863 to 1869 acted as our Corresponding Secretary. He took a similar interest in the Boston Society of Natural History. He was a member, and for many years the President, of the Thursday Evening Scientific Club, to which he imparted new life and vigor, and which was rendered by him an important field of influence. The members who were associated with him in that club will never forget those masterly expositions of recent advances in physical science; and will remember that, while he made clear their technical importance to the wealthy business men around him, he never failed to impress his auditors with the worth and dignity of scientific culture.

During the earlier years of his residence in Boston, Professor Rogers occupied himself with a number of scientific problems, chiefly physical. He studied the variations of ozone (or of what was then regarded as ozone) in the atmosphere at the time when this subject was exciting great attention. He was greatly interested in the improvements of the Ruhmkorff Coil made by Mr. E. S. Ritchie; and in this connection published a paper on the "Actinism of the Electric Discharge in Vacuum Tubes." A study of the phenomena of binocular vision led to a paper entitled "Experiments disproving by the Binocular Combination of Visual Spectra Brewster's Theory of Successive Combinations of Corresponding Points." A paper discussing the phenomena of smoke rings and rotating rings in liquids appeared in the American Journal of Science for 1858, with the description of a very simple but effective apparatus by which the phenomena would be readily reproduced. In this paper Professor Rogers anticipated some of the later results of Helmholtz and Sir William Thomson. In the same year an ingenious illustration of the properties of sonorous flames was exhibited to the Thursday Evening Club above mentioned, in which Professor Rogers anticipated Count Schafgottsch in the invention of a in its prospects, and so complete in its details, that it overshadows all else. A great preacher has said that "every man's life is a plan of God's." The faithful workman can only make the best use of the opportunities which every day offers; but he may be confident that work faithfully done will not be for naught, and must trustingly leave the issue to a higher power. Little did young Rogers think, when he began to teach in Virginia, that he was to be the founder of a great institution in the State of Massachusetts; and yet we can now see that the whole work of his life was a preparation for this noble destiny. The very eloquence he so early acquired was to be his great tool; his work on the Geological Survey gave him a national reputation which was an essential condition of success; his life at the University of Virginia, where he was untrammelled by the traditions of the older universities, enabled him to mature the practical methods of scientific teaching which were to commend the future institution to a working community; and, most of all, the force of character and large humanity developed by his varied experience with the world were to give him the power, even in the conservative State of his late adoption, to mould legislators and men of affairs to his wise designs.

It would be out of place, as it would be unnecessary, to dwell in this connection on the various stages in the development of the Institute of Technology. The facts are very generally known in this community, and the story has been already well told. The conception was by no means a sudden inspiration, but was slowly matured out of a far more general and less specific plan, originating in a committee of large-minded citizens of Boston, who in 1859, and again in 1860, petitioned the legislature of Massachusetts to set apart a small portion of the land reclaimed from the Back Bay "for the use of such scientific, industrial, and fine art institutions as may associate together for the public good." The large scheme failed; but from the failure arose two institutions which are the honor and pride of Boston, — the Museum of Fine Arts and the Institute of Technology. In the further development of the Museum of Fine Arts Professor Rogers had only a secondary influence; but one of his memorials to the legislature contains a most eloquent statement, often quoted, of the value of the fine arts in education, which attests at once the breadth of his culture and the largeness of his sympathies.

Although the committee of gentlemen above referred to had failed to carry out their general plan, yet the discussions to which it gave rise had developed such an interest in the establishment of an institution to be devoted to industrial science and education that they determined upon taking the preliminary steps towards the organization of such an institution. A sub-committee was charged with preparing a plan; and the result was a document, written by Professor Rogers, entitled "Objects and Plan of an Institute of Technology." That document gave birth to the Massachusetts Institute of Technology, for it enlisted sufficient interest to authorize the committee to go forward. A charter with a conditional grant of land was obtained from the legislature in 1861, and the institution was definitely organized, and Professor Rogers appointed President, April 8, 1862. Still, the final plans were not matured and it was not until May 30, 1864, that the government of the new institution adopted the report prepared by its President, entitled "Scope and Plan of the School of Industrial Science of the Massachusetts Institute of Technology," which Dr. Runkle has called the "intellectual charter" of the institution, and which he states "has been followed in all essential points to this very day." In striking confirmation of what we have written above, Dr. Runkle further says: —

"In this document we see more clearly the breadth, depth, and variety of Professor Rogers's scientific knowledge, and his large experience in college teaching and discipline. It needed just this combination of acquirements and experience to put his conceptions into working shape, to group together those studies and exercises which naturally and properly belong to each professional course, and thus enable others to see the guiding lines which must direct and limit their work in its relations to the demands of other departments. . . . .

"The experimental element in our school — a feature which has been widely recognized as characteristic — is undoubtedly due to the stress and distinctness given to it in the 'Scope and Plan.' In our discipline we must also give credit to the tact and large-heartedness of Professor Rogers in the fact that we are entirely free from all petty rules and regulations relating to conduct, free from all antagonism between teachers and students."

The associates of Professor Rogers in this Academy — many of them his associates also in the Institute of Technology, or in the Society of Arts, which was so important a feature of the organization — will remember with what admiration they watched the indefatigable care with which its ever active President fostered the young life of the institution he had created. They know how, during the earlier years, he bore the whole weight of the responsibility of the trust he had voluntarily and unselfishly assumed for the public good; how, while by his personal influence obtaining means for the daily support of the school, he gave a great part of the instruction, and extended a personal regard to every individual student committed to his charge. They recall with what wisdom, skill, tact, and patience he directed the increasing means and expanding scope of the now vigorous institution, overcoming obstacles, reconciling differences, and ingratiating public favor. They will never forget how, when the great depression succeeded the unhealthy business activity caused by the civil war, during which the institution had its rise, the powerful influence of its great leader was able to conduct it safely through the financial storm. They greatly grieved when, in the autumn of 1868, the great man who had accomplished so much, but on whom so much depended, his nerves fatigued by care and overwork, was obliged to transfer the leadership to a younger man; and ten years later were correspondingly rejoiced to see the honored chief come again to the front, with his mental power unimpaired, and with adequate strength to use his well-earned influence to secure those endowments which the increased life of the institution required; and they rejoiced with him when he was able to transfer to a worthy successor the completed edifice, well established and equipped, — an enduring monument to the nobility of character and the consecration of talents. They have been present also on that last occasion, and have united in the acclamation which bestowed on him the title "Founder and father perpetual, by a patent indefeasible." They have heard his feeling but modest response, and have been rejoicing though tearful witnesses when, after the final seal of commendation was set, he fell back, and the great work was done.

We honor the successful teacher, we honor the investigator of nature's laws, we honor the upright director of affairs, — and our late associate had all these claims to our regard; but we honor most of all the noble manhood, — and of such make are the founders of great institutions. In comparison, how empty are the ordinary titles of distinction of which most men are proud! It seems now almost trivial to add that our associate was decorated with a Doctor's degree, both by his own University and also by the University at Cambridge; that he was sought as a member by many learned societies; that he was twice called to preside over the annual meetings of the American Association for the Advancement of Science; and that, at the death of Professor Henry, he was the one man of the country to whom all pointed as the President of the National Academy of Science. This last honor, however, was one on which it is a satisfaction to dwell for a moment, because it gave satisfaction to Professor Rogers, and the office was one which he greatly adorned, and for which his unusual oratorical abilities were so well suited. He was a most admirable presiding officer of a learned society. His breadth of soul and urbanity of manner insensibly resolved the discords which often disturb the harmonies of scientific truth. He had the delicate tact so to introduce a speaker as to win in advance the attention of the audience, without intruding his own personality; and when a paper was read, and the discussion closed, he would sum up the argument with such clearness, and throw around the subject such a glow of light, that abstruse results of scientific investigation were made clear to the general comprehension, and a recognition gained for the author which the shrinking investigator could never have secured for himself. To Professor Rogers the truth was always beautiful, and he could make it radiant.

It is also a pleasure to record, in conclusion, that Professor Rogers's declining years were passed in great comfort and tranquillity, amidst all the amenities of life; that to the last he had the companionship of her whom he so greatly loved; and that increasing infirmities were tended and the accidents of age warded off with a watchfulness that only the tenderest love can keep. We delight to remember him in that pleasant summer home at Newport, which he made so fully in reality as in name the "Morning-side," that we never thought of him as old, and to believe that the morning glow which he so often watched spreading above the eastern ocean was the promise of the fuller day on which he has entered.

NATHANIEL THAYER.

Nathaniel Thayer died at his residence in Boston, March 7, 1883, in the seventy-fifth year of his age, and his well-rounded life, ripe in experience as well as years, can be looked back upon as successful in all that gives that word its best significance. He was born in Lancaster, September 11, 1808, and was educated in the same place. His father, Rev. Dr. Nathaniel Thayer, was minister in that town for nearly fifty years. The very high character of his parents, and all the influences surrounding the years of his youth, tended to implant in the young man the genius that found so rich fruition as he grew to manhood. It is too true, that in the richest soil weeds are most apt to abound; and a parallel is often found in the waste of opportunities which should furnish the way to the best and highest development. In Mr. Thayer's case we see an instance where, from early youth, his tastes and inclinations led his sympathies into association only with the best, so that at all times it was a pleasure and a compliment to be his friend. He was very clear and strong in his estimate of men, which made him a warm, sincere, and devoted friend to those whom he received into his confidence; and his relations with many whom the community has most esteemed were especially pleasant and intimate. The writer recalls the almost brotherly relations he held with many who have been of most service to their day and generation.

To make others happy was Mr. Thayer's highest enjoyment; and could the many he has assisted be gathered together, those who knew him most would be surprised at the multitude. What has been done by Mr. Thayer for Harvard College, for Lancaster (his native town and the place of his summer residence), is well known in this community; but what he has done to assist young men to their education, to aid the widows and families of needy friends and acquaintances, and indeed in a hundred ways, will never be known.

For many years Mr. Thayer, in partnership with his deceased brother, constituted the firm of John E. Thayer and Brother, in Boston, a firm chiefly concerned in the development of the railroad enterprises which have opened the West to intercourse and traffic. Mr. Thayer had the highest sense of business honor, and no name stood higher, the world over, than that of his firm. The springs of action with him were from a deep, conscientious appreciation of the duties attending success, — which comes not of "luck," as so many think, but through careful, well-matured, systematic conduct of business affairs. It is common for many to judge harshly the men who have been successful in business, and one often hears that it is not possible to be an honest man of business; but they little understand that honor and honesty go quite as far as capital in giving business men their standing. Those who knew the subject of this article best need not to be told that he never wilfully wronged any one. All are fallible, and may be in error as to what will prove to be the best permanent investment of money; but he made fewer mistakes in this direction than most men who have managed so large a business.

In his family relations Mr. Thayer was all that was tender and lovely, — thoroughly unselfish. His sympathies were always quick to appreciate what would be for the permanent good of the community and individuals, and he was always ready to assist what commended itself to his judgment. He was strong, manly, self-reliant, pure-hearted, — eager to do his part, and more than his part, to raise the community to a higher level, by aiding institutions of learning, charity, art, or science, and promoting with generous gifts all that the best citizens most esteem.

Nathaniel Thayer was one among the more munificent benefactors of Harvard College who chose to bestow their valued gifts during their own lifetime, having the privilege of witnessing the good uses which they serve. While Mr. Thayer's generosity has its evidences on the subscription papers and donation books of all our multiplied institutions and agencies of science, art, culture, mercy, and charity, his direct benefactions to Harvard University, represented by buildings, endowments, and permanent deposits, exceed a quarter of a million dollars, and include his expenditures on "Thayer Hall," "Thayer Commons Hall," "Gray Herbarium," the "Thayer Expedition," etc. This gross sum is in addition to a considerable amount which for a long series of years, through channels of his own choosing, he has distributed as pecuniary aid to students in the College, and to scholars in preparation for it.

Thayer Hall, erected in 1870, and whose full cost exceeded a hundred thousand dollars, was designed by him as a memorial gift commemorative of his father, Rev. Nathaniel Thayer, D. D., and of his brother, John Eliot Thayer.

His father, Rev. Dr. Thayer, was the honored and revered minister of the beautiful town of Lancaster, in the fair valley of the Nashua, for nearly half a century. Whatever changes necessity or expediency in time to come may introduce in modifying the obligations and relations of Harvard College to the supply of ministers for the churches, it may be claimed that it has, for at least two centuries, answered fully to the intent and pledge of its first planting by a twofold recognition of its responsibility in this direction, and of a large return of gratitude for its services. It has furnished the churches of New England with a succession of faithful Christian ministers; and it has received from the sons of such ministers many of its most devoted and esteemed officers and instructors, and many of its most liberal endowments. Quite a considerable list might be made of the sons of country ministers — some of them, like their fathers, alumni of Harvard, and others who had not enjoyed that privilege — who have spent their lives in the service of the institution, or who have left there generous deposits of the wealth acquired in professional or mercantile life. Dr. Thayer of Lancaster — himself the son of a country minister who had graduated at Harvard in 1753, and a lineal descendant on the maternal side of the famous John Cotton of the old and the new Boston — was a classmate and life-long friend of President Kirkland, of the class of 1789. In dignity, and in the graces and virtues of character, he was one of the best examples of that class of ministers to whom all our old villages and towns since their first settlement looked up for the best instruction and the most faithful guidance in all the nobler interests of life. His gravity and serenity of look and mien gave him a sort of Washingtonian dignity. He belonged to a fellowship of divines very remarkable in their period for weight of professional character, enlarged liberality of views, thorough scholarly culture, and a high tone of life, — including such men as Kirkland, Freeman, Buckminster, Thacher, Bancroft, Channing, and Ware. He was for many years the sole minister of a town of about two thousand inhabitants, and was held in true esteem and love by all his people. Probably no higher or purer gratification could have been afforded him, could he have had the foreknowledge or assurance of it, than that among the venerable halls of the College where he had spent years of happy and faithful pupilage the filial devotion of a son would rear one that should bear his name.

At a time when the high price of board at Cambridge pressed very heavily on the poorer students, Nathaniel Thayer performed for the College another service most needful and helpful, in providing a place and means for such students as wished to avail themselves of a commons hall for boarding at low cost. He enlarged considerably, and in large part furnished, the former station of a branch of the Fitchburg Railroad in Cambridge, as the Thayer Commons Hall. This was in 1865, and it was successfully occupied for ten years, till Memorial Hall gave to the students a splendid new room for that purpose. It was understood that Mr. Thayer expended more than $8,000 in securing and fitting his Commons Hall. Its affairs were managed by the students who there took their meals, the expense to them being simply the cost of the materials for their food, and its preparation. Many of the students who sat at those tables were doubtless the guests of the host.

It was substantially in the service of the University that Mr. Thayer so generously assumed the whole cost of Professor Agassiz's vigorous and most fruitful visit of exploration and research to South America, known as the "Thayer Expedition." This was in the interests of high science, and it has proved the basis of and incitement to advanced stages already reached, and of infinite progress still inviting its pupils. It is believed that the only hesitancy in facing the known and possible obligations to which Mr. Thayer committed himself in this enterprise was in his humorous lament to Professor Agassiz as to the enormous amount of alcohol needed to prepare the fishes of which he appeared to empty the ocean.

The relations between Mr. Thayer and Professor Agassiz were those of the warmest regard and the fullest gratitude. While Agassiz would receive no personal emolument for his laborious work, he had the most generous sense of the claims of high science on men of wealth, and he delighted to give them the most favorable opportunities for advancing it.

Another of the admirable provisions made by Mr. Thayer, through his friend Professor Gray, in meeting the ever-multiplying needs of the University, was in erecting and furnishing, in 1874, at a cost of over $15,000, the fire-proof Herbarium on the grounds of the Botanic Garden.

ASSOCIATE FELLOWS.

CHARLES AVERY.

Charles Avery was born in Munson, Mass., July 29, 1795. He died at his home in Clinton, N. Y., May 20, 1883. He was the son of Gardner Avery and Amy Newell, who in 1810 removed with their large family to Sauquoit, Oneida Co., N. Y. He belonged to a generation which is now fast passing away, when the advantages for education were comparatively rare, and were prized in proportion to their rarity. His early education was the result of his own energy and thirst for knowledge. He early evinced a marked taste for studies in mathematics and science. In a sketch of his own life he said, "At the age of seventeen I found myself at evening solving questions in arithmetic which had been proposed by young pedagogues as challenges." This was the awakening of that love for mathematical investigation which characterized his entire life, — a love to which he gave expression in his old age when he spoke of "the delightful science of figures."

In 1816 he entered Hamilton College, was graduated in 1820, and on October 1, 1822, was married to Delia Strong, daughter of Rev. Joseph Strong of Heath, and sister of Professor Theodore Strong, the distinguished mathematician. After completing his college studies he was engaged for fourteen years in teaching in various academies in the State of New York, — viz. at Horner, Fairfield, and Belleville.

His work as an instructor was successful in a high degree. His success at Horner was such as to give him considerable reputation, and to secure him a call to Fairfield, — a call, the wisdom of which was justified by the immediate additions to the fame and prosperity of the school.

At Fairfield he became favorably known as a mathematician, and students came in some instances from Hamilton College to Fairfield to profit by his instructions. His object in removing from Belleville to Clinton was, in part at least, to open a school for the study of the exact sciences. "Here," said he, "I could indulge in the higher analysis to my heart's content. This I did to my own satisfaction, and much to the delight of my pupils."

In 1834, he was appointed Professor of Chemistry and Natural Philosophy in Hamilton College, the only appointment which has ever been made in that institution to that double chair. The winter of 1834–35 he spent in New Haven in order to attend the lectures of Professor Silliman. He entered upon his work with great enthusiasm, and in a short time brought the department of chemistry, which had suffered from neglect, into a respectable prominence. His success, particularly in detecting poisons, gave him a reputation as an analyst of decided ability, and numerous cases in which questions of medicine and law were involved were brought to him for solution. He introduced into his department, for the first time, the study of chemical analysis and agricultural chemistry, and made the chemical equipment of the College, which had been very meagre, so good as to compare favorably with the best endowed colleges in the land. On November 14, 1838, he was elected a Fellow of the American Academy of Arts and Sciences.

Keenly alive to all matters of experiment or investigation, he entered with great zeal into the studies of Daguerre. He took the first daguerrotype ever taken in this country *west of Albany*, and it might be said *west of New York*, since he taught the artists in Albany how the work could be successfully done. It was owing to his experiments in this art that his health was for a time seriously impaired. In 1844 he was taking daguerrotypes in Rome, N.Y. The operating-room was also used as a lodging-room. The vapors of bromine had so impregnated the air as to make it poisonous, and the sleep of one night resulted in serious and protracted illness. He early saw the value and prominence which astronomical studies were to assume in this country, and largely through his own efforts secured for Hamilton College an Astronomical Observatory. By personal effort Professor Avery added largely to the funds of the College, securing in three different financial campaigns more than one hundred and thirty thousand dollars. During the year which intervened between the resignation of Dr. Fisher and the inauguration of Dr. Braun, by request of the Trustees he acted as President of the College. In 1869, having reached the age of seventy-four, he resigned his chair of instruction.

The closing years of his life were passed quietly in Clinton. A green and cheerful old age, free from complaint and full of genial sympathy, was his enviable portion. He kept up his studies to the end. His mind was characterized by strength and clearness in all logical processes. He was a close observer, and much given to reflection. He was deliberate and cautious in forming his conclusions, and believed nothing so important as accuracy and truth. In all his intercourse with men he was conspicuous for candor and simplicity. He uniformly looked upon the bright side of life. A fund of native humor was always at his command, and he loved the pleasures of social life, which he could well enliven with anecdote and repartee. He was singularly charitable in all his judgments. At peace with God and man, he fell asleep in a good old age, leaving the record of a good and useful life, and beloved and lamented by all who knew him.

HENRY DRAPER.

Henry Draper was born, March 7, 1837, in Prince Edward County, Virginia. He died in November, 1882. His father, Professor John W. Draper, early directed his son's thoughts toward science, and the researches of the son seem to have been the outcome of the father's work. By the death of Henry Draper, the world has lost the accumulated scientific experience of two lives.

John W. Draper began his scientific career as Professor of Chemistry at Boydton, Virginia. It was here that Dr. Henry Draper was born. In 1839 the father was appointed Professor of Chemistry in the University of New York, and the son, at the age of fifteen, entered the Freshman Class of the institution over which the father presided. During the Junior year he left college, entered the Medical School, and graduated with the degree of Doctor in Medicine in 1858. His graduating thesis was a valuable investigation upon the functions of the spleen, by means of microphotography. During the process of this work he discovered the use of palladium protochloride in darkening collodion negatives. His work in college, and especially in the Medical School, gave promise of his future distinction. Those who knew him at that time speak of his scientific tastes and of his bright and active mind. He spent the year after his graduation in Europe, and was especially interested in instruments and appliances for scientific research. It is said that a visit to Lord Rosse's great reflecting telescope turned his attention especially to solar physics. On his return, he entered Bellevue Hospital as an assistant, and retained the position sixteen months. It was his intention to become a practising physician, but in 1860 he accepted the position of Professor of Physiology in the academic department of the University of New York. The civil war, which had just begun, called for the services of all trained young men, and he was appointed, in 1862, surgeon of the Twelfth Regiment of New York Volunteers.

In 1866 he was appointed to the chair of Physiology in the Medical School, and continued in this position until 1873. The present flourishing condition of the School is said to be largely due to his enthusiasm, to his personal contributions, and to his executive ability. While occupying the chair of Physiology he was engaged in many researches. With a fifteen and a half inch reflecting telescope, constructed under his supervision, he took photographs of the moon fifty inches in diameter. In 1872 he built with his own hands a reflecting telescope of twenty-eight inches' aperture, and, in August, 1872, first succeeded in photographing a star spectrum, — that of Vega. During the same year he made a photograph of the diffraction spectrum of the sun, extending from the neighborhood of G to O.

There seem to have been two epochs in his scientific career which are marked by his contributions to science. In the first epoch, from 1864 to 1870, he published the following works: — "A Text-Book of Chemistry." "Philosophical Use of Silvered Glass Reflecting Telescopes" (Phil. Mag.). "Silvered Glass Telescopes and Celestial Photography." "Petroleum, its Importance and its History." "American Contributions to Spectrum Analysis." "Construction of a Silvered Glass Telescope of fifteen and a half inches' Aperture, and its Use in Celestial Photography" (Smithsonian Institution Contributions, Vol. XIV., 1864).

From 1872, and onward till his death, photography played an important part in all his researches, the second epoch having been prepared for during the first. The following are the principal papers which have been published: — "On the Diffraction Spectrum Photography" (American Journal of Science, 1872). "Astronomical Observations on the Atmosphere of the Rocky Mountains" (American Journal of Science, 1877). "Spectra of Venus and α Lyræ in 1877" (American Journal of Science). "Discovery of Oxygen in the Sun by Photography, and a new Theory of the Solar Spectrum." "On the Coincidence of the Bright Lines of the Oxygen Spectrum with Bright Lines in the Solar Spectrum," 1877. "Eclipse of the Sun in July, 1878" (published in 1878). "Photographing the Spectra of the Stars and Planets," 1879. "Photography of Jupiter's Spectrum, and Photographs of the Nebula in Orion," 1880. "Photographs of the Spectrum of the Comet of June, 1881."

His work upon the photography of stellar spectra continued from 1872 until his death, and he has left a large number of valuable photographs, which promise to exercise great influence upon the direction of modern astronomical investigation. Although he began with the use of reflectors, most of his subsequent astronomical work was done with an eleven and a half inch refractor. With this instrument he made his well-known photographs of the Nebula of Orion.

In 1874 he superintended the photographic work of the Transit of Venus Commission, and the United States government in honor of his able work caused a special gold medal to be struck, which bears upon the face the words, "Decori decus addit avito," and upon the reverse, "Famam extendere factis, hoc virtutis opus."

Perhaps his most famous investigation is that upon the presence of oxygen in the sun. The results of this investigation are, if fully substantiated by subsequent observers, extremely important. The method of procedure was to photograph the solar spectrum side by side with that of oxygen. The entire investigation is well worthy of study, not from its results alone, but from its refined and delicate methods. In the photographs the bright lines of the oxygen spectrum coincide with certain bright spaces between the dark lines of the solar spectrum. In regard to the conclusions of Dr. Draper, Prof. C. A. Young of Princeton remarks: "Naturally there has been some scepticism and discussion as to the correctness and soundness of his conclusions; but no one with an unprejudiced mind can, we think, resist the evidence after careful examination of the plates, especially those obtained during his second and still more elaborate investigation of the subject in 1878–79." This investigation illustrates the scientific position of Dr. Draper better, perhaps, than any we can choose. His early training as a chemist, his active years spent in the mysteries of photography, and his ample fortune, fitted him to undertake such an investigation. It is by reflecting upon the methods of this work, and upon its results, that we can appreciate how much the scientific world has lost. At present, photography seems the most potent means for studying the light of the stars, for unravelling the mysteries of the sun, and for estimating the energy of molecular movements in general.

The practical photographer speaks to-day of loading the molecules by putting various gums into emulsions in order to make the molecules vibrate slower. This metaphorical expression is extremely suggestive, and opens to the imagination the immense field in which Dr. Draper was a master. Photography has already shown us the solar spectrum far beyond the limits of the visible red, and it is said that, had Dr. Draper lived even through the brief space of a twelvemonth longer, he would have succeeded in photographing stars which could not be detected, through the telescope he was using, by the eye.

GEORGE PERKINS MARSH.

George Perkins Marsh was born at Woodstock, in the State of Vermont, on the 15th of March, 1801. He was elected an Associate Fellow in Class III., Section 2, of the Academy, on the 29th of January, 1851. He died at Vallombrosa, in Italy, on the 24th of July, 1882, closing peacefully a long career of great and unceasing usefulness in the service of the republic and of learning.

We cannot wonder that the death of a man so pure, so kindly, so noble and earnest in purpose, and so strong in deed, should call forth, as it does, the reverent and loving sorrow of two nations that he loved perhaps equally, and which he had successfully striven to bring into relations of serviceable friendship during the years in which he represented the one at the court of the other. This republic has lost a loyal, watchful, wise, and able servant, who has caused its name to be honored and loved, not only by reason of his eminent diplomatic services during twenty-five years, but also by the power of his personal worth. United Italy grieves as for a foster-father, who brought to the help of its trembling infancy the strong sympathy of a sturdy republic in the vigor of its early prime. Perhaps it will never be fully known how greatly this noble man strengthened the hands of both the kings of new Italy, as they struggled to break away from the chains of priestcraft and the relics of feudalism into the freedom of self-government.

How high a rank our late Associate held as a student and expounder of truth in the fields of natural science, of philosophy, of political economy, of archæology, of philology, and of literature, is attested by the many learned societies, both in this and in other countries, that deemed it an increase of honor to themselves to write his name in their lists of members.

What Mr. Marsh was as a friend and counsellor is happily known to many whom his generous heart embraced in those intimate relations. How dear he must have been to those who stood within the circle of his family, they alone can know. We feel that their loss is unspeakable, and we can only draw near to their sacred sorrow with our best offerings of earnest sympathy for them, and of profound reverence and admiration for him.

Such is the man whose name death has struck from our roll. We look with desire for a full account of his life from some hand competent to the grateful task. In such a memoir we shall hope to find a just estimate of Mr. Marsh's public services to his native State and to the Republic, both at home and abroad, and also of his scientific and literary work. In the mean while a short outline of his life may fitly be put on record here, together with a brief account of his published writings.

George Perkins Marsh was graduated a Bachelor of Arts by Dartmouth College in the class of 1820. He also received from his College the Master's degree in course. Harvard College and Delaware College honored him with the degree of Doctor of Laws in 1859, and Dartmouth College did the same in 1860. He was, at the time of his death, a member of this Academy, of the Massachusetts Historical Society, and of the American Philosophical Society, not to speak of others in this country, and of many foreign societies.

Having taken his first college degree, Mr. Marsh established himself at Burlington, Vermont, where he read and practised law. In 1835 he served in the legislature of Vermont, and he represented that State in Congress from 1842 to 1849. In the latter year he was commissioned by President Taylor as Minister Resident of the United States at Constantinople. He remained at that post until 1853. In 1852 the United States intrusted him with a special mission of peculiar delicacy to the King of Greece, "to adjust the difficulties that had sprung up between the Greek government and the Rev. Jonas King, acting Vice-Consul of the United States." The profound knowledge of the principles of international law, as well as of the Greek constitutional law, which Mr. Marsh displayed in his masterly conduct of these negotiations, appears to have made a strong impression of his learning and skill among European statesmen. At the close of his residence at Constantinople, Mr. Marsh returned to America, where his executive ability and scientific acquirements were at once enlisted in various public services by his native State. The years between 1853 and 1861 were spent by Mr. Marsh in these services, and in preparing and publishing several philological and scientific works, and in delivering lectures in Washington, New York, and Boston. In 1861 President Lincoln accredited Mr. Marsh as Envoy Extraordinary and Minister Plenipotentiary of the United States at the Court of Italy. He continued to hold this honorable office until he died.

Besides numerous minor writings, including his contributions to periodical publications, and besides any writings which his literary executors may yet bring to light, Mr. Marsh left several larger published works which may conveniently be arranged in two classes.

To the first class belong the two works entitled, respectively, "The Earth as Modified by Human Action," and "The Camel, his Organization, Habits, and Uses, considered with Reference to his Introduction into the United States." The former of these books is a corrected and enlarged edition of an earlier work of the same author, entitled "Man and Nature, or Physical Geography as modified by Human Action."

This book, upon which Mr. Marsh's reputation could well afford to rest, is, like his other works, characterized by thoroughness, earnestness and practical good sense. It does not profess to be a scientific work, but to address itself to the common sense of men of average intelligence, for purposes merely practical.

The work is so complex in its structure, and so full of details as heterogeneous as they are important, that it can only be analyzed in the most general terms. Its general scope is to exhibit the exceptional position of man, as distinguished from all other living organisms, in respect to the power of influencing the aspect and the operations of Nature; and to inculcate the wisdom and the duty of directing this power according to the dictates of sound reason and the teachings of experience, so as not only to reach the best results and avoid former errors, but also to remedy, so far as is still possible, the evil already caused by inexperience and want of caution.

Man, who in his savage state is a mere consumer of what Nature has provided, soon becomes a producer, using to that end, and modifying to a remarkable extent, the powers of Nature of which he has learned the secret more or less completely. That he shall learn it most thoroughly so far as such knowledge is permitted to him, and that he shall use due caution in his interference with Nature's spontaneous operations, is the author's wise endeavor.

Mr. Marsh approached the work in his wonted spirit of earnestness, and with that faithful preparation which he brought to all that he attempted. The works which he consulted are more than three hundred in number, and are written in a dozen languages. To give credit in detail to each author for what he has found useful in his works would have encumbered the book with an intolerable bulk of references. The author has wisely avoided doing so whenever the matter did not seem to require, by its novelty or strangeness, the support of some recognized authority. In these cases the statement is generally given in the words and with the name of the writer who is responsible for it.

The book has three principal divisions. First, an introductory chapter exhibits the character, extent, and variety of man's action on Nature. Next, four chapters treat in detail of man's influence upon animal and vegetable life, the forest, the waters, and the sands. Finally, a most suggestive and useful chapter deals with the great projects which this century has brought forth for the modification of the physical character of our globe.

Under the first of these heads we are shown how some of the most flourishing provinces of the Roman Empire have been brought to a condition of hopeless decay by neglect of those terms which Nature imposes upon those to whom she permits such wonderful control over her own operations. Man, who could not exist in a civilized state without in a measure unbalancing Nature's stable equilibrium, has persistently exceeded that measure. His action has, on the whole, been destructive, although in some places and in recent times there is a reverse to this melancholy picture. There are regions first peopled by Europeans not more than two hundred years ago which already show signs of dilapidation.

The author then enters upon a detailed description of man's interference with Nature in respect to animal and vegetable life, showing how he promotes the growth of certain species of plants and animals often changing their nature in a wonderful degree by his care and cultivation, — how he greatly reduces the numbers of other animals and plants, often altogether expelling certain animals from particular regions, and sometimes, though rarely, effecting, or at any rate greatly hastening, the annihilation of certain species. Mr. Marsh illustrates the matter by copious examples culled from his prodigious and encyclopedic reading. It would be hopeless to attempt to give any adequate idea of their variety and interest. Few men indeed are so minutely acquainted with historical botany and zoölogy, and with the practical side of natural history, as not to find in these pages a rich harvest of the most interesting and instructive details.

No less remarkable is the author's chapter on forests, their position in the economy of Nature, their influence on climate, on torrents and inundations, on health, and the importance of man's operations involving their destruction or conservation.

Waters and their management are treated with the same mastery of details. It is shown how, by man's various devices for obstructing, directing, and in general governing water, the action of tides and the fauna and flora of regions may be altogether changed, whether beneficially or injuriously.

Even dry sands are invested with an interest not their own. The value of dunes, and the details of their wise management, are made the subject of one of the most interesting chapters of this most interesting book.

But the part of the work which will perhaps most engage the attention of the general reader is the concluding chapter, in which Mr. Marsh has examined by the light of wisdom and experience all the great projects proposed within the last quarter of a century for the extensive modification of the face of Nature. In this chapter he discusses such vast subjects as the cutting of isthmuses like Suez and Darien, the proposed canal to open the Dead Sea, the Caspian and Azof Canal, the flooding of the Lybian Desert, and the diversion of the Colorado River for the reclaiming of the great Colorado Desert, and incidentally discusses such living questions as the damage caused by hydraulic mining, and even the extent to which volcanic action may be subject to man's control. And lest the consideration of such immense results of man's action should blind the reader to the equal importance of little agencies repeatedly brought into action, the author concludes his work with this eminently philosophical remark. "In the vocabulary of Nature," says he, "little and great are terms of comparison only; she knows no trifles, and her laws are as inflexible in dealing with an atom as with a continent or a planet."

This last remark is but one of many keen and clever bits of philosophy with which the work abounds. Mr. Marsh keeps ever in view the peculiar needs and dangers of the two nations that shared his best affections, America and Italy, and he is abundant in practical suggestions for both countries. His views of history are large and clear, especially in regard to the influence of education and of civil and religious liberty. The man's generous nature appears in this, as well as in the frank tribute which he willingly pays to Elisée Reclus, his only rival in this branch of literature.

Mr. Marsh's style is always clear and direct. In his choice of words he is not rigidly a purist. When such words as "degradation," meaning the wearing away of the surface of a hill-side, or the like, or "flotation," come handy, he uses them without apology. Even the American words "lumber" and "lumberman" he does not disdain.

In a work of this nature mere diction is, of course, a secondary matter; yet the reader occasionally meets with some concise sentence which reveals remarkable epigrammatic force, and a passage here and there full of poetic beauty.

And if the reader would know how a man occupied in the varied labors of a life like Mr. Marsh's could find the time or the will to produce a work like this, he will find his answer in the author's admirable disquisition, on pages 11–14 of this book, upon the duty and profit of learning to see. "Sight," says he, "is a faculty; seeing, an art. To the natural philosopher, the descriptive poet, the painter, the sculptor, and indeed every earnest observer, the power most important to cultivate, and at the same time hardest to acquire, is that of seeing what is before him." This power Mr. Marsh had acquired to a high degree, and had so well used it to fill his memory with an infinite variety of useful facts that their expression, when digested in the alembic of his judicious mind, must have been to him as much a delight and a necessity as to another it would have been a labor and a weariness; for from the abundance of the heart the mouth speaketh.

The monograph on the Camel belongs to the period in which Mr. Marsh was Minister of the United States at Constantinople. "The practicability and expediency of introducing the camel into the United States" had engaged his attention "as a problem of much economical interest," even before he went to Turkey. In that country he was able to investigate the subject yet more fully. He also turned to good account several months of travel in Egypt, Nubia, Arabia Petræa, and Syria, and he likewise saw the camel at work in Constantinople and at different points in Asia Minor. Besides these personal observations, he gathered such information as he could by inquiry and correspondence, and by consulting the books of travel and natural history to which he had access. "By these means," he says in his Preface, "I arrived at a strong persuasion of the probable success of a judiciously conducted attempt to naturalize in the New World this oldest of domestic quadrupeds, and at the same time I collected most of the materials which compose the following pages." After his return to America he added to his previous sources of information the valuable treatises of Ritter, Carbuccia, and others.

Before Mr. Marsh's treatise was printed, he had delivered a lecture covering some of the same ground before the Smithsonian Institution, which incorporated it in one of its Reports. The occasion for publishing the book appears to have been given by the discussions in Congress on the question of "importing camels for army transportation and for other military purposes," which culminated in an appropriation of money to this end.

Mr. Marsh's handling of this subject shows the spirit in which he studied all subjects. His work never was that of a dilettante. By original investigations he would form clear and strong convictions, which he would then carefully compare with the opinions of other observers, never failing to reach substantial practical conclusions. Of this treatise on the Camel he says, "I claim no merit but that of fidelity in presenting the conclusions at which I have arrived." "I have intended," he adds, "to take a purely practical view of my subject, and I have, therefore, sought to condense into the limits I have prescribed to myself the greatest possible amount of information, and to fortify my statements by the most reliable authorities." A rapid survey of this book will show how well the author carried out his purpose.

In a brief introductory chapter he reminds us that the Creator commanded man to subdue the earth, and invested him with dominion over all terrestrial creatures. Man has, as yet, fulfilled but a part of this proud destiny. Of all the *vegetable* and *animal* products of the globe at least, comparatively few have been subdued to human use, still fewer permanently domesticated in our fields and our households. The proper *savage* only asks of *inorganic* Nature the gifts which she spontaneously offers him. But even in the very dawn of social life, man demands of the *organic* world, not merely the usufruct of its spontaneous productions, but the complete appropriation and domestication of many species of both plants and animals. We accordingly owe to our primeval, untutored ancestors the discovery, the domestication, and the acclimatization of our cereal grains, our edible roots, and our improved fruits, as well as the subjugation of our domestic animals, while *civilized* man has directed his efforts under the Creator's commission almost exclusively to the conquest of the *inorganic* creation, and has scarcely reclaimed a plant of spontaneous growth, or added a newly tamed animal to the flocks and herds of the pastoral ages.

Many of the domesticated families of the organic world are peculiarly suited to the uses of man as a migratory animal, and are apparently almost exempted from subjection to climatic laws, and accordingly follow him in all his wanderings. Others seem to be inexorably confined within prescribed geographical bounds. Others, again, though comparatively independent of climate and of soil, are nevertheless specially fitted to certain conditions of surface, and to certain modes of human life, to the maintenance of which they are themselves indispensable.

In the second chapter Mr. Marsh goes on to show that the camel belongs to the last-mentioned class of domesticated animals. Nature has adapted this quadruped chiefly to the desert, where he acquires his true significance and value, his remarkable powers being the necessary condition and sole means by which man has in any degree extended his dominion over the Libyan and the Arabian wildernesses, for example. But as society advances in refinement, the camel gives place to animals better suited to the wants and caprices of higher civilization. Even the enclosing of land for agricultural uses, and the superseding of the coarse herbage of spontaneous growth by artificial vegetation, are unfavorable to his full development and physical perfection. Hence the attempts to introduce the camel into Spain, Italy, and other European countries have met with at best a very indifferent success.

Mr. Marsh next examines the several species and breeds of the camel, in a series of learned chapters on the general and special anatomy of this animal, treating in detail of the hump, the head, the foot (adapted as well to the yielding sands as to the rugged rocks), and of the complicated structure of the stomach. Then follows a chapter on the size, color, diseases, temper, and longevity of the animal; after which the useful products of the camel, and his diet and powers of abstinence, are examined. His training and treatment form the next division of the subject. The author here gives us, upon the best authorities, an astonishing estimate of the great carrying power of the camel, and shows us the proper mode of saddling him for this service. Precise statements follow of the camel's speed and gait. Then, after having relieved the severity of his discussion by quoting from another writer an interesting and instructive passage on the characteristic pleasures and pains of travel by camel caravan, and after an allusion to the almost incredibly great number of camels employed in Egypt and other Mussulman countries, Mr. Marsh goes on to discuss the "geographical range" of the several species. One species is found in perfection in some of the hottest countries on the globe. Another bears with impunity the severities of Northern winters. The geographical range of the camel has been greatly extended even in comparatively recent times, and Mr. Marsh confidently expected that this animal would be naturalized in yet other regions, including New Mexico and California.

Having thus fully established the great value of the camel as a helper in man's work, the author answers affirmatively the ultimate question whether any large tracts of our territory possess the climate and soil best fitted to the animal's usefulness. He shows that our Trans-Mississippian regions, and our Southwestern territories, including the southern passes of the Rocky Mountains, possess all the requisite conditions. In the closing chapter he traces the use of the camel for military purposes from the earliest historical times to the present, and sets forth the expediency of employing the animal in these services in the United States, especially against our hostile Indian tribes.

Mr. Marsh had the satisfaction of seeing the introduction of the camel tried by our government with so much wisdom and skill as to elicit his warmest praise of all those who had a share in the experiment. He forgets, however, to claim any praise for his own distinguished services in the matter.

The book has an index, which places its valuable contents readily at the reader's command.

While the books that have just been analyzed may be called scientific, those of the second group belong to the provinces of philology, literary history, and archæology. The largest of Mr. Marsh's works in these departments are the courses of lectures delivered by him, in New York and Boston respectively, upon the English Language. The first of these was given at Columbia College in the years 1858–59, and published under the name of "Lectures on the English Language"; the second was delivered at the Lowell Institute in 1860–61, and issued with the title of "Origin and History of the English Language, and of the early Literature it embodies." Another of his philological works is the admirable enlarged edition of Wedgwood's Dictionary of English Etymology.

Mr. Marsh's attainments in the Scandinavian languages and lore were early recognized and honored by the learned societies of Northern Europe. One fruit of his studies in that direction was a Grammar of the Icelandic Language, compiled from the several works of Rask, the Danish philologist.

The antiquarian researches of Mr. Marsh are represented by the careful study that he made of the position and influence of the Goths in history, even tracing the Gothic element in the Puritans of New England.

The two groups into which we have ventured to divide Mr. Marsh's writings combine their forces to prove how vast and exact was his learning, and how thorough and judicious were his methods of intellectual work. But it is the first group that specially exhibits his individual characteristics. There we see him pursuing a wholly new inquiry, and again conducting triumphantly the investigation of a subject so abstruse, so vast, and so complex, that it is fair to say he had no rival in the work. These two books of his must long remain the classics in their respective provinces. It is for these reasons that an analysis of them has been attempted here. In the second class of subjects, on the other hand, Mr. Marsh was one of many laborers. The study of language, in its several divisions, has been many years enlisting a larger and larger number of able scholars. Moreover, in the rapid progress of modern philology, any man's labors, be they never so eminent, may soon be superseded, wholly or in part. We are very far, however, from intimating that any such destiny has overtaken Mr. Marsh's philological or literary works. They will ever be storehouses of precious materials; and they are now, in their latest revisions, so fully abreast of the most recent discoveries, that no earnest student of English philology can afford to neglect them, or is in danger of doing so. All these considerations render it inexpedient to essay here the analysis of any book of Mr. Marsh's in this department; nor, indeed, could any fair analysis be made that should not transgress the reasonable limits of a notice like this.

An account of Mr. Marsh and his work would fall far short of completeness, even in form, without some allusion to his remarkable library. No monument can be reared to the memory of a man of letters more fitting than the one he has reared for himself in the collection of books that he gathered about him as the instruments and helpers of his daily tasks. The scholar's loves and purposes are embodied in his library as truly as in his published work; often, perhaps, even more fully.

This library is described as containing twelve thousand volumes, some miscellaneous and modern, "many rare, valuable, ancient, and curious." The languages of Northern and Central Europe are, of course, largely represented; those of Southern Europe probably no less so. For Mr. Marsh's attention had been fixed, for several years before his death, on the revival, which is even now in progress, of the noble Catalan dialect and of the Provençal, and his intimate study of the Italian language had led him, long before, into the less frequented paths of its literature. One of his cherished plans had been that of a complete English-Italian Dictionary which should adequately register the "grammatical relations" of the words in each language, and should be worthy of both. As he felt his own strength declining, he often tried to persuade younger students to engage in this work.

By the liberality of an alumnus of the University of Vermont, of which Mr. Marsh was for a time one of the Trustees, this precious collection of books has been secured for that institution. It is to be regretted that these literary treasures were not deposited where the largest numbers congregate of those who would turn them to good account. Yet, while we deplore the limitation of its usefulness, we cannot but be glad that Mr. Marsh's library, unlike that of the late Mr. Benfey and other valuable collections, has found a large-minded and large-hearted man who would not allow its collective force to be destroyed.

ISAAC RAY.

ISAAC RAY, M. D., LL. D., was born at Beverly, Mass., January 16, 1807, and died in Philadelphia, March 31, 1881.

Dr. Ray graduated from Phillips Academy and Bowdoin College, teaching school during vacations in order to help defray his expenses. He took his degree of Doctor of Medicine at the Harvard Medical School in 1827, and at once began practice in Portland, Maine, where he was married in 1831. Soon after, removing to Eastport in the same State, he published (in 1838) his "Medical Jurisprudence of Insanity," a book of which the sixth edition has recently appeared, and which has remained for more than forty years the leading work in the English language upon that subject.

Dr. Ray was Medical Superintendent of the State Hospital for the Insane at Augusta, Maine, from 1841 to 1846. He was then appointed to take charge of the building of the Butler Hospital for the Insane at Providence, R. I., of which he was the head for twenty years after its completion. He was also for a few months in charge of the McLean Asylum at Somerville, Mass., but failing health compelled him to seek a milder climate, and the last fourteen years of his life were spent in Philadelphia, very much saddened toward the end by the death of his only surviving child, a son, practising medicine, and having his office in his father's house. Dr. Ray was one of the organizers of the Association of Medical Superintendents of American Institutions for the Insane, in 1844, and was its President from 1855 to 1859. He was a most careful student, having visited Europe to examine the hospitals there, and a most assiduous writer upon the various subjects of interest in his branch of the medical profession. His "Mental Hygiene," a series of lectures delivered before the Lowell Institute in Boston, published in 1863, and his "Contributions to Mental Pathology," collected for publication in 1873, illustrate the thoroughness of his work, his earnestness of purpose, and his clear, vigorous style.

Dr. Ray was not only for more than a quarter of a century the acknowledged head of the alienists in this country, but, deeply interested in all that pertains to the welfare of the human race, he was also one of the leading sanitarians and social scientists of his day, contributing freely from his abundant resources to the proceedings of the American Public Health Association and the Social Science Association. As one of the directors of the Blockley Almshouse and Hospital in Philadelphia, he was a practical reformer of institution abuses. During his whole professional career, he was one of the foremost in adopting the more progressive views of recent years in treating the insane with increasing freedom, and in endeavoring to make their lives as little unlike the lives of the sane as possible. The monument of his life's work is the Butler Hospital, built under his own eyes, beautified and improved from year to year as larger experience suggested, from the chapel of which he chose to be buried, and to which he bequeathed the greater portion of his property, subject to his widow's life interest in it.

Dr. Ray's wisdom, purity of character, and faithfulness to every duty, won the regard of his fellow-men. His unremitting care of his patients gained their affectionate esteem, as his genial manner, wide information, and wonderful powers of conversation captivated their attention and drew them away from their morbid thoughts. During a long and painful illness his courage never failed. During an active life of more than threescore years and ten, in which he often saw the worst side of human nature, his faith in mankind never faltered.

FOREIGN HONORARY MEMBERS.

THEODORE LUDWIG WILHELM VON BISCHOFF.

Theodore Ludwig Wilhelm von Bischoff, who died at Munich on December 5, 1882, was born at Hannover, October 28, 1807. His father was Christian Heinrich Ernst Bischoff, a physician who held professorships at Berlin and Bonn, and was the author of several works on medicine and chemistry. The younger Bischoff began his studies with his father, and pursued them at Düsseldorf, Bonn, and

Heidelberg, receiving the degree of Doctor of Philosophy in 1829, and that of Doctor of Medicine in 1832. He obtained an appointment as assistant in midwifery at Berlin. Here he met with Johannes Müller and Ehrenberg, under whom he continued his studies in anatomy and physiology. From 1835 to 1843 he delivered lectures on comparative pathological anatomy at Heidelberg, and from 1843 to 1855 was Professor of Physiology and Anatomy at Giessen, where he established a Museum of Anatomy and a Physiological Institute. In 1854, having declined offers from several German universities, he accepted the chair of Human Anatomy and Physiology at Munich, succeeding the anatomist Foerg.

In 1850, he appeared with Liebig at the famous trial of Count Görlitz, who was accused of wife-murder, and demonstrated the impossibility of spontaneous combustion. His views on this subject may be found in his paper, "Ueber die Selbstverbrennung," in the *Annales de la Médecine Légale*, 1850.

Bischoff belonged to the older school of German embryologists, who under the lead of Von Baer laid the foundations of modern morphology. He paid considerable attention to the anatomy of the Quadrumana, and his last papers were devoted to the comparative study of the brain of monkeys. His more important memoirs, however, are his investigations on the development of Mammalia, published between 1842 and 1852. The monographs he published on the Dog, the Guinea-Pig, the Rabbit, and the Deer have remained the basis of all the more recent studies on the development of the higher mammals.

Bischoff was elected Foreign Honorary Member of this Academy, November 13, 1849, and his letter acknowledging his election, dated at Giessen, May 20, 1850, is worthy of being preserved, as showing his large and liberal spirit: —

"This unexpected honor, paid me from a land so distant from my native country, possesses for me a high worth, as an evidence of the acknowledgment of my scientific labors and exertions. It encourages me to hope that these labors possess a generally useful character, and that they have acquired the approbation of the patrons of science in your society. This marked honor is flattering to me also, inasmuch as it furnishes fresh evidence that the United States, so long the asylum of my poor and oppressed countrymen, forced to leave their native Germany, will also kindly receive German science, fostering and advancing it upon a more fruitful ground than can be found in the much overcrowded fatherland."

JOSEPH LIOUVILLE.

Joseph Liouville came into the world of science from a highly esteemed family of Lorraine. He was born on Friday, March 24, 1809. In 1827 he was graduated, with marked distinction, at the École Polytechnique, being classed in the service of the *Ponts et Chaussées*. But he renounced the career thus opened to him, and determined to devote his life to the advance of science and to the work of education. In 1831 he became instructor (*répétiteur*), and in 1838 professor, at the École Polytechnique. He was called later to professorships at the Collége de France and at the Sorbonne; and in the active discharge of his duties at the Collége de France he remained up to his death. He became a member of the Academy of Sciences in 1839, and of the Bureau of Longitudes in 1841. In the revolutionary year 1848 he was elected to the Constituent Assembly as a representative of Moselle, and was distinguished there, according to M. Laboulaye, for his clearness and fluency of speech; but, on the expiration of his official term, he gladly withdrew from a life which only unusual emergencies had induced him to enter. In 1836 M. Liouville founded the *Journal de Mathématiques Pures et Appliquées*, which he edited, with distinguished ability, for a period of thirty-nine years, down to 1875. This publication, which is still everywhere known by his name, is a lasting monument of his industry and scientific power, and has contributed greatly to the influence and reputation of French geometers. The later years of Liouville's life were saddened by severe domestic griefs and by failing health. But his mind remained unclouded and active. He undertook, but was unable to finish, his course at the Collége de France in the last year of his life. He was present at a meeting of the Bureau of Longitudes two days before his death; which took place, suddenly at the last, on Friday, September 8, 1882.

M. Liouville has been an eminent figure among the mathematicians of his day, an able, vigorous, and original worker in the field of science, an example of simple self-devotion, and the centre of an important influence. The titles of his memoirs occupy very nearly twelve pages in the Royal Society Catalogue of Scientific Papers to 1873 inclusive. These writings, treating chiefly of subjects in pure analysis, contain many valuable contributions to mathematical science, and are marked by a beauty of form which is itself a mathematical excellence. They have helped to give a shape to the scientific thought of our time. As an editor and a professor also M. Liouville has exerted a strong regulating and stimulating influence. He was a brilliant and inspiring lecturer; and it was into his professorial work that he threw the fulness of his strength, discerning, training, encouraging, and bringing forward the mathematical genius of a generation, and impregnating it, in his admirable courses, with fertile germs of new discovery. He was no less happy in addressing the Academy. M. Faye, in his speech at the grave of Liouville, tells us that he was in his prime a powerful scientific orator, and that he was equalled only by Arago in ability to give to a general scientific audience a sense of real insight into the abstruse conceptions of the higher analysis.

M. Liouville was chosen a Foreign Honorary Member of this Academy in 1859, as successor to Cauchy. We have lost in him one who has played an important part in the development of mathematical knowledge during the past half-century.

EMILE PLANTAMOUR.*

Emile Plantamour, Professor of Astronomy and Director of the Observatory at the University of Geneva, died at Geneva, September 7, 1882. He was born at Geneva, May 14, 1815, and received his early education in the old college founded by Calvin, after which he spent eight years in the then celebrated school of Hofrozl. In 1833 he entered the Geneva Academy, where he became one of the astronomer Gautier's most promising pupils. After graduating in philosophy, he resolved to make the study of astronomy the work of his life, a design in which he was encouraged by Gautier, who, on account of an affection of his sight, promised to vacate his chair in Plantamour's favor when the latter had completed his university education. From Geneva Plantamour proceeded to Paris, where he studied for two years under Arago. He was also a pupil of Bessel at Königsberg, where, in 1839, he took the degree of Doctor, the subject of his thesis being the methods of calculating the orbits of comets. From Königsberg he went to Berlin, and worked for some time with Encke, who recognized in his quickness of observation and aptitude for complex calculations his special fitness for the career to which he intended to devote himself. On his return to Geneva Plantamour received the double appointment of the Professorship of Astronomy in the Academy

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* This notice is taken chiefly from the Monthly Notices of the Royal Astronomical Society of London, February, 1883.

(which has since been transformed into a University) and Director of the Observatory. In 1848 he accepted also the chair of Physical Geography, and he retained all three positions until his health began to fail him, a few months before his death. His publications chiefly related to atmospheric electricity, observations of comets, and meteorological observations made on the Great St. Bernard. Special reference should be made to the important investigations of the diurnal oscillations of the soil undertaken by him by means of spirit-levels, and of which accounts are given in the *Comptes Rendus* for 1878 and 1879. Much of his time was devoted to meteorology, and his papers in the *Bibliothèque Universelle* on the subject were numerous; he was also one of the most active members of the Helvetic Scientific Society for the observation of atmospheric phenomena. He devoted attention to geodesy, and in 1861 became the representative of Geneva on the Paris Geodetic Commission. He was also a useful member of the International Geodetic Association, which met a few years ago at Geneva. In connection with the Genevan Society of Arts he organized a watch and chronometer competition, which has proved of great value to the staple industry of Geneva. Watches and chronometers are sent to the Observatory and tested there, the results being published, and prizes awarded to the best time-keepers. Four years ago he added to the Observatory at his own expense a refractor of ten inches' aperture, and he erected the building for its reception. He was a man of fortune, and might have devoted his life to social enjoyment and ease; but he was deeply attached to science, and preferred to retain his posts at the University, although the modest salary he received scarcely covered his expenses.

Plantamour's early work on cometary astronomy must not be passed over unnoticed. One of his most elaborate investigations was his determination of definite elements of Mauvais's comet of 1844, which was observed from July 7 in that year to the middle of March, 1845, and therefore offered a favorable opportunity for the calculation of the true form of orbit. Plantamour's result was a somewhat notable one: after taking into account the effect of the attraction of the planets during the comet's visibility, he concluded that at the passage through perihelion in October, 1844, the comet was moving in an elliptical orbit with a period of revolution of 102,050 ± 3,090 years. In 1846 he made extensive calculations bearing upon the motion of the two heads of Biela's comet, the results of which will be found in No. 584 of the *Astronomische Nachrichten*. He further discussed the elements of what was called at the time "Galle's second comet," 1840,

II. (*Astron. Nach.*, No. 475, 476). In this paper he pointed out some anomalies in the intensity of the comet's light similar to what have been observed from time to time in other comets.

Plantamour was a Corresponding Member of the Academy of Sciences of the Institute of France, having been elected as successor to the elder Struve. He was also a Corresponding Member of the Royal Academy of Sciences of Turin, and an Associate of the Royal Astronomical Society of London. He was elected a Foreign Honorary Member of this Academy on March 13, 1878.

FRIEDRICH WÖHLER.

Friedrich Wöhler, after a long manhood full of the fruits of well-directed intellectual labor, after a tranquil, honored, happy old age, died on the 23d of September last, surrounded by a loving family, and in the full possession of his faculties. He was born on the 31st of July, 1800, in the village of Eschenheim, near Frankfort-on-the-Main. He entered the Gymnasium in Frankfort in his fourteenth year, and there his boyish fondness for experiment quickly ripened into a strongly marked taste for chemistry and mineralogy, for the study of both of which sciences he had accidental facilities which influenced his whole after life. At the age of twenty he entered the University of Marburg, where he passed a year, and where, in a small extemporized private laboratory, he began the study of the compounds of cyanogen, his first paper on that subject appearing in Gilbert's *Annalen*, in 1821. From Marburg he went to Heidelberg, and there worked in the laboratory of Leopold Gmelin, whose influence upon him was very marked, and who quickly perceived in him the promise of future eminence. Here he published two papers on cyanic acid. He had at this time the prospect of becoming a physician, and took his degree as Doctor of Medicine in September, 1823. The urgency of Gmelin decided him to devote himself exclusively to chemistry, and, after a brief correspondence and warm recommendation from Gmelin, Berzelius agreed to receive him into his laboratory. The charming account which he wrote in his old age of Berzelius himself, of his own residence and travels in Sweden and Norway, and of various distinguished men whom he met, is familiar to all chemists. Wöhler spent nearly a year in Sweden, forming a friendship with Berzelius which was never interrupted, and which ended only with the life of the latter. He at first settled in Heidelberg as Privatdocent, but by the advice of Berzelius, Gmelin, and Von Buch, in 1825 went to Berlin. and there became teacher of chemistry and mineralogy in an industrial school founded by Von Bärensprung. While in Berlin he succeeded in isolating aluminum by the action of sodium upon aluminic chloride, and published papers upon various other subjects. In 1828, while still in Berlin, he made his memorable discovery of the synthesis of urea. We who are familiar with the artificial preparation of alizarin, of indigo-blue, and of citric and uric acids, and who can see the shadow of the coming syntheses of chinim and morphine, find it perhaps difficult to understand the influence of Wöhler's discovery in the year 1828. But, as the first synthesis of an organic body from the elements, it marks the beginning of an era in the history of chemistry.

In 1831 Wöhler removed from Berlin to Cassel, where his wife's family resided, and where he obtained a professor's chair in the Gewerbschule. Before this, however, his lifelong friendship with Liebig had been formed, and when, in 1832, his young wife died, Wöhler sought for a time a congenial home with Liebig in Giessen. There the two produced their noble study of the oil of bitter almonds, — an investigation received with a general burst of admiration, and which roused even the calm nature of Berzelius to enthusiasm. In 1836 Wöhler succeeded Stromeyer at Göttingen, and was succeeded at Cassel by Bunsen. Then came the grand work with Liebig on uric acid. To this succeeded a long series of papers, partly in conjunction with Liebig, partly his own exclusively. The complete list of Wöhler's writings includes two hundred and seventy-five titles. There is no department of chemistry not enriched by his labors. Many of his papers are very short, but every one is at least suggestive. Every method in analytical chemistry which he gave admitted of generalization. Nearly all the rarer elements passed through his hands, and perhaps no chemist ever had so wide an experience.

Wöhler had a mind fertile in methods, and a judgment seldom at fault. His character was singularly well balanced, and an inborn, keen sense of humor kept his whole nature sweet and wholesome. His pupils were warmly attached to him. They celebrated his sixtieth and seventieth birthdays, and the fiftieth anniversary of the discovery of the synthesis of urea. But on his eightieth birthday chemists of all lands united to honor the grand old man. Contributions poured in from all quarters, and not last or least from our own country. A beautiful marble medallion in a frame of bronze was the form which the memorial assumed, and which, worthily bestowed, was accepted with a few dignified and touching words. In 1880 the old chemist published his last paper, — a brief notice of a galvanic element containing aluminum. The decline of his long life had all that makes old age endurable, — the society of family friends and pupils, freedom from sickness or serious infirmity, a reasonable competence, and an honest, well-earned consciousness of a life full of usefulness and without stain.

Since the last Report, the Academy has received an accession of eighteen new members; viz. nine Resident Fellows, one Associate Fellow, and eight Foreign Honorary Members. One member has resigned, and another has abandoned his fellowship. The list of the Academy corrected to the date of this Report is hereto added. It includes one hundred and ninety-four Resident Fellows, ninety Associate Fellows, and seventy-two Foreign Honorary Members.

LIST

OF THE FELLOWS AND FOREIGN HONORARY MEMBERS.

RESIDENT FELLOWS.—194.

(Number limited to two hundred.)

Class I.—*Mathematical and Physical Sciences.*—72.

Section I.—6.

Mathematics.

William E. Byerly,	Cambridge.
Benjamin A. Gould,	Cambridge.
Gustavus Hay,	Boston.
James M. Peirce,	Cambridge.
John D. Runkle,	Brookline.
Edwin P. Seaver,	Newton.

Section II.—13.

Practical Astronomy and Geodesy.

J. Ingersoll Bowditch,	Boston.
Seth C. Chandler, Jr.,	Cambridge.
Alvan Clark,	Cambridgeport.
Alvan G. Clark,	Cambridgeport.
George B. Clark,	Cambridgeport.
John R. Edmands,	Cambridge.
Henry Mitchell,	Boston.
Robert Treat Paine,	Brookline.
Edward C. Pickering,	Cambridge.
William A. Rogers,	Cambridge.
Arthur Searle,	Cambridge.
Leopold Trouvelot,	Cambridge.
Henry L. Whiting,	Tisbury.

Section III.—38.

Physics and Chemistry.

A. Graham Bell,	Cambridge.
Clarence J. Blake,	Boston.
Francis Blake,	Auburndale.
John H. Blake,	Boston.
Thos. Edwards Clark,	Williamstown.
W. S. Clark,	Amherst.
Josiah P. Cooke,	Cambridge.
James M. Crafts,	Boston.
Charles R. Cross,	Boston.
William P. Dexter,	Roxbury.
Amos E. Dolbear,	Medford.
Charles W. Eliot,	Cambridge.
Moses G. Farmer,	Newport.
Thomas Gaffield,	Boston.
Wolcott Gibbs,	Cambridge.
Frank A. Gooch,	Cambridge.
Edwin H. Hall,	Cambridge.
Henry B. Hill,	Cambridge.
N. D. C. Hodges,	Salem.
Silas W. Holman,	Boston.
Eben N. Horsford,	Cambridge.
T. Sterry Hunt,	Montreal.
Charles L. Jackson,	Cambridge.
William W. Jacques,	Newburyport.
Leonard P. Kinnicutt,	Cambridge.
Joseph Lovering,	Cambridge.
Charles F. Mabery,	Cambridge.
William R. Nichols,	Boston.
John M. Ordway,	Boston.
William H. Pickering,	Boston.
Robert H. Richards,	Boston.
Edward S. Ritchie,	Brookline.
Stephen P. Sharples,	Cambridge.
Francis H. Storer,	Jamaica Plain.
John Trowbridge,	Cambridge.
Cyrus M. Warren,	Brookline.
Charles H. Wing,	Boston.
Edward S. Wood,	Cambridge.

Section IV.—15.

Technology and Engineering.

George R. Baldwin,	Woburn.
John M. Batchelder,	Cambridge.
Charles O. Boutelle,	Washington, DC.
Henry L. Eustis,	Cambridge.
James B. Francis,	Lowell.

John B. Henck,	Boston.
E. D. Leavitt, Jr.,	Cambridgeport.
William R. Lee,	Roxbury.
Frederic W. Lincoln,	Boston.
Hiram F. Mills,	Lawrence.
Alfred P. Rockwell,	Boston.
Charles S. Storrow,	Boston.
William R. Ware,	New York.
William Watson,	Boston.
Morrill Wyman,	Cambridge.

CLASS II. — *Natural and Physiological Sciences.* — 60.

SECTION I. — 8.

Geology, Mineralogy, and Physics of the Globe.

Thomas T. Bouvé,	Boston.
William T. Brigham,	Boston.
Algernon Coolidge,	Boston.
William O. Crosby,	Boston.
Jules Marcou,	Cambridge.
William H. Niles,	Cambridge.
Nathaniel S. Shaler,	Cambridge.
Charles U. Shepard,	Amherst.

SECTION II. — 8.

Botany.

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Asa Gray,	Cambridge.
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Charles S. Sargent,	Brookline.
Charles J. Sprague,	Boston.
Edward Tuckerman,	Amherst.
Sereno Watson,	Cambridge.

SECTION III. — 22.

Zoölogy and Physiology.

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Joel A. Allen,	Cambridge.
Robert Amory,	Brookline.
Nath. E. Atwood,	Provincetown.
James M. Barnard,	Boston.
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Edward Burgess,	Boston.
Samuel Cabot,	Boston.
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Samuel H. Scudder,	Cambridge.
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Henry Wheatland,	Salem.
James C. White,	Boston.

SECTION IV. — 22.

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Henry I. Bowditch,	Boston.
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Frank W. Draper,	Boston.
Thomas Dwight,	Boston.
Robert T. Edes,	Boston.
Calvin Ellis,	Boston.
Charles F. Folsom,	Boston.
Richard M. Hodges,	Boston.
Oliver W. Holmes,	Boston.
Robert W. Hooper,	Boston.
Alfred Hosmer,	Watertown.
Edward Jarvis,	Dorchester.
Francis Minot,	Boston.
John P. Reynolds,	Boston.
Wm. L. Richardson,	Boston.
George C. Shattuck,	Boston.
J. Baxter Upham,	Boston.
Charles E. Ware,	Boston.
John C. Warren,	Boston.
Henry W. Williams,	Boston.

Class III. — *Moral and Political Sciences.* — 62.

Section I. — 14.

Philosophy and Jurisprudence.

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Phillips Brooks,	Boston.
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James B. Thayer,	Cambridge.

Section II. — 18.

Philology and Archæology.

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Epes S. Dixwell,	Cambridge.
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Charles R. Lanman,	Cambridge.
Bennett H. Nash,	Boston.
Frederick W. Putnam,	Cambridge.
John L. Sibley,	Cambridge.
E. A. Sophocles,	Cambridge.
John W. White,	Cambridge.
Justin Winsor,	Cambridge.
Edward J. Young,	Cambridge.

Section III. — 19.

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Edward Atkinson,	Boston.
John Cummings,	Woburn.
Charles Deane,	Cambridge.
Charles F. Dunbar,	Cambridge.
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George E. Ellis,	Boston.
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William Gray,	Boston.
Edward Everett Hale,	Boston.
Henry P. Kidder,	Boston.
Henry C. Lodge,	Boston.
Francis Parkman,	Boston.
Andrew P. Peabody,	Cambridge.
Joseph S. Ropes,	Boston.
Henry W. Torrey,	Cambridge.
Francis A. Walker,	Boston.
Robert C. Winthrop,	Boston.

Section IV. — 11.

Literature and the Fine Arts.

Charles F. Adams,	Boston.
George S. Boutwell,	Groton.
J. Elliot Cabot,	Brookline.
Francis J. Child,	Cambridge.
Charles G. Loring,	Boston.
James Russell Lowell,	Cambridge.
Charles Eliot Norton,	Cambridge.
Thomas W. Parsons,	Wayland.
Charles C. Perkins,	Boston.
H. H. Richardson,	Brookline.
John G. Whittier,	Amesbury.

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Class I.—*Mathematical and Physical Sciences.*— 36.

Section I.—7.

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William Ferrel,	Washington, D.C.
Thomas Hill,	Portland, Me.
Simon Newcomb,	Washington, D.C.
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James E. Oliver,	Ithaca, N.Y.
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Section II.—13.

Practical Astronomy and Geodesy.

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Wm. H. Emory,	Washington, D.C.
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George W. Hill,	Nyack, N.Y.
Sam. P. Langley,	Allegheny, Pa.
Elias Loomis,	New Haven, Conn.
Maria Mitchell,	Poughkeepsie, N.Y.
C. H. F. Peters,	Clinton, N.Y.
George M. Searle,	New York.
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Section III.—11.

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W. A. Norton,	New Haven, Conn.
Ogden N. Rood,	New York.
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Section IV.—5.

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W.P.Trowbridge,	New Haven, Conn.

Class II.—*Natural and Physiological Sciences.*— 28.

Section I.—13.

Geology, Mineralogy, and Physics of the Globe.

George J. Brush,	New Haven, Conn.
James D. Dana,	New Haven, Conn.
J. W. Dawson,	Montreal, Canada.
J. C. Fremont,	New York.
F. A. Genth,	Philadelphia.
Arnold Guyot,	Princeton, N.J.
James Hall,	Albany, N.Y.
F. S. Holmes,	Charleston, S.C.
Clarence King,	Washington, D.C.
Joseph Le Conte,	Berkeley, Cal.
J. Peter Lesley,	Philadelphia.
R. Pumpelly,	Newport, R.I.
Geo. C. Swallow,	Columbia, Mo.

SECTION II. — 3.

Botany.

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G. Engelmann,	St. Louis, Mo.
Leo Lesquereux,	Columbus, Ohio.

SECTION III. — 7.

Zoölogy and Physiology.

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Joseph Leidy,	Philadelphia.
O. C. Marsh,	New Haven, Conn.
S. Weir Mitchell,	Philadelphia.
A. S. Packard, Jr.,	Providence.

SECTION IV. — 5.

Medicine and Surgery.

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W. A. Hammond,	New York.
Alfred Stillé,	Philadelphia.

CLASS III. — *Moral and Political Sciences.* — 26.

SECTION I. — 7.

Philosophy and Jurisprudence.

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R. G. Hazard,	Peacedale, R.I.
Nathaniel Holmes,	St. Louis, Mo.
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Noah Porter,	New Haven, Conn.
Jeremiah Smith,	Dover, N.H.

SECTION II. — 8.

Philology and Archæology.

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A. D. White,	Ithaca, N.Y.
W. D. Whitney,	New Haven, Conn.
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SECTION III. — 6.

Political Economy and History.

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S. G. Brown,	Hanover, N.H.
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M. F. Force,	Cincinnati.
W. G. Sumner,	New Haven, Conn.

SECTION IV. — 5.

Literature and the Fine Arts.

James B. Angell,	Ann Arbor, Mich.
L. P. di Cesnola,	New York.
F. E. Church,	New York.
R. S. Greenough,	Florence.
William W. Story,	Rome.

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(Appointed as vacancies occur.)

CLASS I.—*Mathematical and Physical Sciences.*—22.

SECTION I.—5.

Mathematics.

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Brioschi,	Milan.
Arthur Cayley,	Cambridge.
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SECTION II.—7.

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SECTION III.—9.

Physics and Chemistry.

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SECTION IV.—3.

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CLASS II.—*Natural and Physiological Sciences.*—28.

SECTION I.—7.

Geology, Mineralogy, and Physics of the Globe.

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SECTION II.—7.

Botany.

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Oswald Heer,	Zurich.
Sir Joseph D. Hooker,	London.
Carl Nägeli,	Munich.
Julius Sachs,	Würzburg.

Section III. — 10.

Zoölogy and Physiology.

Milne Edwards,	Paris.
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Albrecht Kölliker,	Würzburg.
Rudolph Leuckart,	Leipsic.
C. F. W. Ludwig,	Leipsic.
Richard Owen,	London.
Louis Pasteur,	Paris.
C. Th. von Siebold,	Munich.
J. J. S. Steenstrup,	Copenhagen.
Valentin,	Berne.

Section IV. — 4.

Medicine and Surgery.

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Virchow,	Berlin.

Class III. — *Moral and Political Sciences.* — 22.

Section I. — 3.

Philosophy and Jurisprudence.

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James Martineau,	London.
Sir James F. Stephen,	London.

Section II. — 7.

Philology and Archæology.

Georg Curtius,	Leipsic.
Pascual de Gayangos,	Madrid.
Benjamin Jowett,	Oxford.
Lepsius,	Berlin.
Max Müller,	Oxford.
H. A. J. Munro,	Cambridge.
Sir H. C. Rawlinson,	London.

Section III. — 8.

Political Economy and History.

Ernst Curtius,	Berlin.
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Mommsen,	Berlin.
Mark Pattison,	Oxford.
Von Ranke,	Berlin.
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Section IV. — 4.

Literature and the Fine Arts.

Matthew Arnold,	London.
Gérôme,	Paris.
John Ruskin,	Coniston.
Alfred Tennyson,	Isle of Wight.

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University Press: John Wilson & Son, Cambridge.